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JOURNAL OF ANATOMY

NEOPALLIAL MORPHOLOGY OF FOSSIL MEN AS STUDIED FROM ENDOCRANIAL CASTS.

By Professor M. BOULE (*Muséum d'Histoire Naturelle, Paris*) and Professor R. ANTHONY (*École d'Anthropologie, Paris*).

THE very accurate researches of Professor J. Symington, as to what might be learned of human cerebral morphology from the observation of the endocranial cast,[1] have led him to confirm an anatomical fact which has long been considered by everyone as a commonplace, and upon which we have very particularly insisted at the beginning of our paper concerning the encephalon of the La Chapelle aux Saints Man,[2] namely, that *an endocranial cast can afford but incomplete and conditional information about the morphology of the neopallial foldings.*[3]

Having considered, nevertheless, that such conditions did not render a study of endocranial casts fruitless and ineffectual, we were deeply surprised that Professor Symington's researches should have led him to the following conclusions:—

"1. That the simplicity or complexity of the cerebral fissures and convolutions cannot be determined with any degree of accuracy from endocranial casts, even from complete skulls, much less from reconstructions from imperfect skulls.

[1] J. Symington, "On the Relations of the Inner Surface of the Cranium to the Cranial Aspect of the Brain": The Sir John Struthers Anatomical Lecture, delivered at the Royal College of Surgeons of Edinburgh on 16th December 1914: *Edinburgh Medical Journal*, Feb. 1915. The author also presented the results of that study to the Anatomical Society of Great Britain and Ireland (see *Proceedings*, 1916).

Id., "Endocranial Casts and Brain Form: a Criticism of some recent Speculations," *Journal of Anatomy and Physiology*, Jan. 1916.

[2] M. Boule et R. Anthony, "L'encéphale de l'homme fossile de La Chapelle aux Saints," *L'Anthropologie*, mars-avril 1911.

[3] G. Elliot Smith says: "The beautiful series of casts which Professor Symington has shown do not demonstrate anything that anatomists have not been familiar with for a century at least; for every time one removes a carefully hardened brain from the cranium, all the points mentioned by Professor Symington obtrude themselves on the attention." ("An Answer to Professor Symington," *Proc. Anat. Soc. of Great Britain and Ireland*, Jan. 1916.)

"2. That it is not possible to estimate, even approximately, from the La Chapelle or Piltdown endocranial cast the relative degree of development of the various sensory and association centres in the cortex.

"3. That the various deductions made by Boule, Anthony, Elliot Smith, and others, with reference to the primitive and simian features of the brain of certain prehistoric men, from an examination of their endocranial casts, are highly speculative and fallacious."[1]

First, we might note with Professor G. Elliot Smith that "because many specimens afford negative evidence is surely no reason for refusing to recognise positive information of the most definite character when it occurs."[2]

It would be regrettable in every respect if we should refuse to avail ourselves in palæontology of the endocranial casts which are able to give us, on the one hand, positive information on all that relates to the general shape of the encephalon, and, on the other, valuable indications on the morphology of the dura mater sinuses, the meningeal vessels, and even, as admitted indeed by Professor Symington[3] himself, on the shape and position of the Sylvian complex at its opening, as well as, generally speaking, of the neopallial foldings that lie in the orbital region, along the lower external edge of the hemispheres, at the anterior end of the temporal lobe.

The identification of the other convolutions is, of course, much less certain, but must we refrain from starting any discussion about them and from presenting hypotheses even supported by arguments?

We shall first examine the broad question how far and in what measure the results of Professor Symington's researches, applicable indeed to modern Man, are so for fossil men; and secondly, we shall review those of our own conclusions which the author has thought fit to reject.

It is well known that if there are Mammals, such as modern Man and Cetaceans, concerning the neopallial foldings of which the study of endocranial casts can afford but incomplete information, there are others, such as Carnivores and Ungulates, in which the neopallial foldings are so plainly printed on the endocranial cast, as well on the roof as on the sides

[1] J. Symington, *Journal of Anatomy and Physiology*, 1916, *loc. cit.*, p. 130.

[2] G. Elliot Smith, "An Answer to Professor Symington," *Proc. Anat. Soc. of Great Britain and Ireland*, Jan. 1916.

[3] J. Symington, *Edinburgh Medical Journal*, *loc. cit.*, pp. 98 and 99. In his address to the British Association in 1903 (see *Report*, p. 794), Professor Symington himself urged the importance of making such use of endocranial casts as we have done.

and the base, that they can be read on a cast nearly as easily and with as much exactitude and precision as on the surface of the brain itself. G. Schwalbe[1] in 1904, and one of us[2] in 1903, drew attention to that important fact, which many former works, more particularly those of P. Gervais, had already disclosed. Moreover, both R. Anthony and G. Schwalbe proved that in some members of the Mustelidæ group, for instance, a certain number of neopallial foldings are recognisable on the surface of the endocranial cast.[3]

While in modern Man, as Professor Symington[4] has remarked, the foldings, plainly visible at the base of an endocranial cast, become less

FIG. 1.—Endocranial cast of *Indris brevicaudatus* E. Geoffr. (Anatomie comparée, Muséum d'Histoire naturelle, Paris, No. A 10,595). Norma verticalis, showing the clearness and the precision of the neopallial impressions.

and less so as you draw nearer to the vertex, it is otherwise in some Primates—Lemurs, for instance,—in which the distinctness and extent of

[1] G. Schwalbe, "Über die Beziehungen zwischen Innenform und Aussenform des Schädels," *Deutsches Archiv f. klinische Medizin*, Bd. lxxiii., 1904.

Id., "Über das Gehirnrelief des Schädels bei Saügetieren," *Zeitschr. f. Morphol. und Anthrop.*, Bd. vii., 1904.

Id., "Über das Gehirnrelief des Schläfengegend des menschlichen Schädels," *Zeitschr. f. Morphol. und Anthrop.*, Bd. x., 1907.

[2] R. Anthony, "Introd. à l'étude expérim. de la Morphogénie. Modifications craniennes consécutives à l'ablation d'un crotaphyte chez le chien, et considér. sur le rôle morphogénétique de ce muscle," *Bull. et Mém. Soc. Anthrop. de Paris*, 1903.

[3] R. Anthony et G. Schwalbe, *loc. cit.* In his 1907 memoirs Schwalbe showed that even in human endocranial casts the prominence of the convolutions is visible on the surface of the fossa temporalis.

[4] J. Symington, *Edinburgh Medical Journal*, *loc. cit.*, pp. 98–99.

their cerebral endocranial impressions are similar to those seen in Carnivores and Ungulates.

Everyone is acquainted with Professor G. Elliot Smith's[1] remarkable studies on the endocranial casts of the extinct Lemurs of Madagascar (not to mention the series of memoirs on the endocranial casts of other mammals—see *Transactions of the Linnean Society*, 1899 and 1903, and the Catalogue of the brains and cranial casts in the Museum of the Royal College of Surgeons, 1902).

Monkeys and Apes, considered from that standpoint, are not exactly similar to Man, nor to Carnivores, Ungulates, and Lemurs. If the

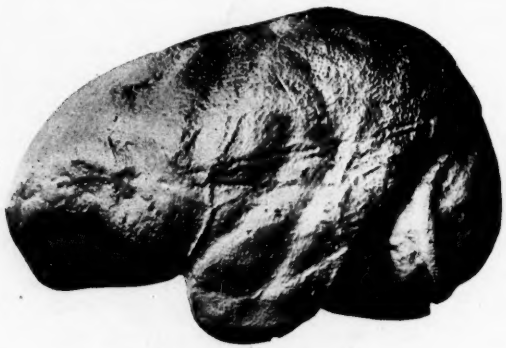

FIG. 2.—Endocranial cast of [*Hylobates leuciscus* Schreb. (Anatomie comparée, Muséum d'Histoire naturelle, Paris, No. A 8102). Left norma lateralis, showing sufficiently precise and clear neopallial impressions.

endocranial casts of Chimpanzees, Gorillas, Orang-outangs are particularly akin, with respect to the vagueness and extent of their impressions, to those of human skulls, those of Cercopithecinæ and the Gibbon still retain on their whole surface neopallial impressions which, although not sharply defined in some cases, are yet always unmistakable. Therefore the value of the information that the study of endocranial casts may afford about neopallial morphology is very different according to the types considered.

The question to be decided is this: What definite inferences may we draw from a study of fossil men's endocranial casts?

[1] G. Elliot Smith, "On the Form of the Brain of the Extinct Lemurs of Madagascar, with some Remarks on the Affinities of the Indrisinæ," *Trans. of the Zool. Soc. of London*, vol. xviii. part ii., May 1908.

An examination of the endocranial casts of La Chapelle, La Quina, and Neanderthal justifies the conclusion that the region in which neopallial foldings are plainly demonstrated extends further forwards and backwards in them than in those of modern Man. These fossil men, viewed from that standpoint, would be, as it were, the link between the latter and the Gibbon.

The clearness and extent of neopallial impressions on the endocranial cast of an animal depend of course on many factors, all of which it would be difficult to enumerate.[1] But it seems that platycephaly is

FIG. 3.—Endocranial cast of Gorilla (Anatomie comparée, Muséum d'Histoire naturelle, Paris, No. A 8026). Left norma lateralis on which neopallial impressions are neither clear nor precise.

certainly to be considered as one cause, for we notice that, whereas in the Gibbon, the most platycephalic among Anthropoid Apes, foldings are to be seen imprinted on the whole endocranial surface, in modern Man they persist only at the base—by reason, probably, as previously said, of the force of gravity. In Neanderthalians, endocranial impressions of the furrows are more plainly perceivable, being usually apparent on the surface of the frontal and occipital regions. The following figures clearly express the great platycephaly of the Neanderthalians compared with modern men:—

[1] *Cf.* about that question, R. Anthony, "Introd. à l'étude expérimentale de la Morphogénie, etc.," *Bull. et Mém. Soc. Anthrop. de Paris*, 1903.

1. *Vertical longitudinal cranial index of Schwalbe.*

Neanderthalians	La Quina	39·09 [1]
	Neanderthal	40·4 [2]
	La Chapelle	40·5 [3]
Minimum in modern Man		45 [4] (an Australian)

2. *Frontal angle of Schwalbe.*

Neanderthalians	Neanderthal	44° [5]
	La Quina	45° [6]
	La Chapelle	45·5° [7]
Minimum in modern Man		50° [8] (a South Australian)

Moreover, the following observation may be accepted as supporting our contention:—the vertical longitudinal cranial index of Pithecanthropus is 34·2, the frontal angle is 34°,[9] and Dubois, speaking of its endocranial cast, says: "In the frontal region of the hemispheres the convolutions are most perfectly distinct."[10]

The fact, however, that the Chimpanzee, the Gorilla, and the Orang, still more platycephalic than Neanderthalians, afford, in most cases, a nearly smooth endocranial cast, shows that cranial flatness is not the only condition to be taken into account in this matter.

Professor Symington's mistake lies, we think, in assuming implicitly and without question—in spite of the researches of one of us,[11] as well as of Henri Martin[12] and others, concerning the various parts of the skeleton—that what is true of modern Man must also necessarily be true of a Neanderthalian.

But, if we admit that on the endocranial cast of a modern Man there is

[1] H. Martin, *Bull. Soc. préhistorique française*, 1912, p. 32.
[2] G. Schwalbe, *Verhandl. d. anat. Gesells.*, 1901, p. 49.
[3] M. Boule, *Ann. de Paléontologie*, 1911, p. 36. The impressions of the frontal and occipital furrows are somewhat plainer in La Quina than in La Chapelle Man, and R. Anthony's remarks concerning the former have corroborated those previously made concerning the latter. It is regrettable that Professor Symington did not take them into account. . . . R. Anthony, "L'encéphale de l'homme fossile de La Quina," *Bull. et Mém. Soc. Anthrop. de Paris*, 6 mars 1913.
[4] Sollas, *Phil. Trans.*, 1907, p. 285.
[5] G. Schwalbe, *Verhandl. d. anat. Gesells.*, 1901, p. 46.
[6] H. Martin, *Bull. Soc. prehistorique française*, 1912, p. 32.
[7] M. Boule, *Ann. de Paléontologie*, 1911, p. 41.
[8] G. Schwalbe, *Zeitsch. f. Morph. und Anthrop.*, 1899, p. 149.
[9] *Ibid.*, 1899.
[10] Eugène Dubois, "Remarks upon the Brain Cast of *Pithecanthropus erectus*," *Proceedings of the Fourth International Congress of Zoology*, held in Cambridge in 1898.
[11] M. Boule, *Annales de Paléontologie*, 1911.
[12] H. Martin, *Bull. Soc. préhistorique française*, 1912.

a certain region in which neopallial foldings may be identified almost with certainty, it will be found that this region will be extended both further forwards and further backwards on a Neanderthalian cast (fig. 4).

From re-perusal of the papers relating to the endocranial casts of the La Chapelle aux Saints,[1] La Quina,[2] and Neanderthal[3] crania, it seems clear to us:—

Firstly, that we sufficiently emphasised the fact of the hypothetical character of some of our suggestions in reference to neopallial morphology;[4] and

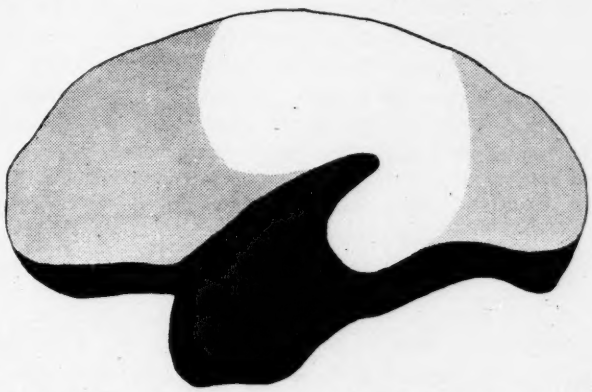

FIG. 4.—Scheme showing the regions of an endocranial cast in the highest Primates, where the neopallial impressions are usually sufficiently clear and precise.

Black-tinted = modern Man.
Black-tinted and grey-tinted = Neanderthalian Man.
The whole norma lateralis = Gibbon.

Secondly, that we laid special stress upon the lack of clear indications of the neopallial features upon the upper surface of the cast, as is the case in most human and anthropoid specimens. Does not our tediously long discussion of the probable place and general direction of the central sulcus[5] afford positive proof of the fact that we refrained from assuming the presence of features of which no trace could be detected?

Consequently, Professor Symington's arguments and criticism are wholly irrelevant.[6]

[1] M. Boule et R. Anthony, *loc. cit.*, *L'Anthropologie*, mars-avril 1911.
[2] R. Anthony, *loc. cit.*, *Bull. et Mém. Soc. Anthrop. de Paris*, 6 mars 1913. [3] *Ibid.*
[4] See M. Boule et R. Anthony, *loc. cit.*, *L'Anthropologie*, mars-avril 1911.
[5] *Ibid.*; and also R. Anthony, *loc. cit.*, *Bull. et Mém. Soc. Anthrop. de Paris*, 6 mars 1913.
[6] J. Symington, *loc. cit.*, *Journal of Anatomy and Physiology*, Jan. 1916, pp. 117–122.

With reference to the probable position of the Sylvian fissure and its anterior and posterior pre-Sylvian branches, which we tried to determine, there is no doubt indeed that in modern Man (as Professor Symington says) most frequently no groove is found on the endocranial cast corresponding to the two pre-Sylvian branches, and the important groove (very often well marked) crossing the lateral boundary of the orbital surface corresponds to lateral offshoots of the sulcus orbitalis.

But in the La Chapelle aux Saints Man the aspect of the same region is very different (perhaps because of the great importance of its platycephaly). The aspect of this region of the La Chapelle aux Saints endocranial cast is also found in the specimen from La Quina. But we have said enough to expound the arguments in justification of our interpretations. "If any such arrangement of parts (the arrangement supposed by M. Boule and R. Anthony) actually existed in the Chapelle brain, it would form an interesting comparison with a fœtal brain of about the seventh month."[1] This is precisely our opinion. We are supposing that if Professor Symington had examined the paper on the interpretation of the La Quina endocranial cast, and had glanced over the figures contained therein, especially figure 20,[2] he would be satisfied with the probability of our interpretation.

Recalling the want of details figured on the roof of the endocranial cast, we are surprised that in his representation of the norma verticalis (fig. 7 according to Boule and Anthony, as he says) Professor Symington indicated the upper part of the central fissure (C.F.), which is not indicated in our figure 8.[3]

It is clear also that if in the same figure the beginning of the depression *Spo* is considered as the very probable point of emergence of the incisura parieto-occipitalis, the whole depression does not represent this incisura.

As a general conclusion we are venturing to assert—

That the results of Professor Symington's researches, though of value for modern Man, are not necessarily valid for the interpretation of a fossil Neanderthal Man, where the shape of the cranium is so different.

Therefore it is not only permissible, but we think highly desirable, to endeavour in the case of this fossil Man, as well as for any fossil Primate, to determine what positive information can be obtained from the endocranial cast, the only material available for such a purpose.

[1] J. Symington, *loc. cit.*, *Journal of Anatomy and Physiology*, Jan. 1916, pp. 119–120.
[2] R. Anthony, *loc. cit.*, *Bull. et Mém. Soc. Anthrop. de Paris*, 6 mars 1913.
[3] Compare fig. 7 in Symington, *Journal of Anatomy and Physiology*, Jan. 1916, with fig. 8 in M. Boule et R. Anthony, *L'Anthropologie*, mars-avril 1911.

THE INTRINSIC ANATOMY OF THE LARGE NERVE TRUNKS OF LIMBS.

By ALWYNE T. COMPTON.

THE surgery of the nervous system has received a considerable impetus during the past few months; and the results of improved technique in primary and secondary nerve-suture, nerve-implantation, and nerve-grafting are becoming definitely known. Operations of this kind are increasingly frequent. It is therefore a matter of interest and importance to gain a knowledge of the finer macroscopic structure of the chief nerve-trunks, more especially in the limbs, in order that, where a choice exists, the surgeon may select that method by which the normal anatomical and physiological conditions may be restored as completely as possible.

With a view to throwing light upon this subject, the conditions of several nerves are being investigated in the adult as well as in the fœtus. In this paper the results of the study of six fœtal and as many adult sciatic nerves are recorded.

The objects of the investigation are four: to ascertain whether it is possible to trace the course of the various nerve-bundles within the trunk of the great sciatic; to determine the relative positions of these bundles; to discover, if possible, some trustworthy marks upon the sheath or surface of the nerve-trunk, which may serve as guides to the position of subjacent nerve-bundles; and, lastly, to note the levels at which the several branches leave the nerve-trunk.

A brief summary of the results of the investigation will be found at the end of the paper. But it will be well to state here, firstly, that it is fairly easy, especially in the fœtal nerve-trunk, to isolate the bundles without injuring them. The whole trunk is enclosed in a tough connective-tissue sheath. From the deep surface of this sheath a number of septa pass inwards among the nerve-bundles, investing each bundle with a tubular sheath. Some of these septa are firmly adherent to the outer sheath, while others are looser and more delicate, and therefore more easily separated from the adjacent nerve-bundles. Some bundles are very easily isolated, while others need the most careful manipulation to free them from their sheath. The posterior tibial nerve was easy to isolate on account of the looseness of its sheath. Incidentally it may be

mentioned that the sheath of this nerve was distinguished in most of the cases examined by being more vascular than the others. With regard to the possibility of determining the relative positions of the bundles in the sciatic trunk, it may be said that as a rule this point presented no difficulties, and that it has been possible to map out the position of each bundle fairly accurately. Unfortunately, no landmarks of any value could be found upon the sheath of the sciatic trunk which might be used as guides to determine the position of the various nerve-bundles. It was hoped at the outset that such landmarks might be furnished by the blood-vessels which pierced the sheath or were distributed upon its surface.

The exact points at which the branches leave the trunk are not quite constant. It is difficult to avoid stripping up a nerve a little too far when cleaning it. It then has the appearance of coming off the trunk at a higher level than is actually the case. The nerve to the femoral head of the biceps leaves the actual nerve-trunk above the level of the ischial tuberosity; but the point at which it emerges from the sheath of the trunk may be two or three inches below the tuberosity. The same applies to several other branches.

The methods employed in this investigation were dissection of hardened and fresh nerves, and the examination of transverse sections made through fœtal limbs showing the sciatic nerve *in situ*. The dissections were carried out with the aid of a lens. Each nerve was traced into the trunk, a note being made of its point of exit. The nerve was then followed upwards upon the surface of the trunk or through its substance, as the case might be. In the hardened nerves it was possible, by avoiding all unnecessary displacement of parent trunk or branch, to determine the position and course of each nerve-bundle. The shape of the transverse section of each larger bundle could also be made out, and how its shape was influenced by the pressure of neighbouring bundles. Each bundle was isolated for a short distance at first, so as not to alter its relation to the surrounding nerves. The bundle next to it was then treated in the same way, and the process repeated until, little by little, the whole sciatic trunk had been examined. During the dissection, measurements were constantly taken, and drawings were made both of the surface of the sciatic trunk and of transverse sections.

The portion of the great sciatic nerve which has been investigated is that which lies below the lower margin of the gluteus maximus muscle.

The sciatic trunk is usually more than half an inch broad, oval in section, its surfaces looking antero-posteriorly, except where it lies to

the outer side of the ischial tuberosity. In this region the trunk is slightly twisted round its long axis, its posterior surface looking outwards as well as backwards.

Branches of the Great Sciatic Nerve.

The exact levels at which the branches are given off vary somewhat. The nerve to the femoral head of the biceps pierces the sheath of the sciatic trunk two to three inches below the tuber ischii. It is derived from the peroneal division, and enters the muscle close to the upper part of its posterior free border. The nerves to the ischial head of the biceps, the semitendinosus, the semimembranosus and adductor magnus muscles come off either separately or by a common trunk from the inner side of the tibial division of the great sciatic. In either case they leave the tibial one to two inches below the ischial tuberosity. The nerve to the ischial head of the biceps passes downwards and, inclining slightly outwards, crosses the main trunk posteriorly and enters the biceps upon its inner and deep surface three to four inches below the tuberosity. The nerves to the semitendinosus are two in number. They enter the deep surface of the muscle, one above and the other below the tendinous intersection. The upper branch reaches the muscle about three inches below the tuberosity, the lower branch about the middle of the thigh. The nerve to the semimembranosus is long and rather slender. It enters the cleft between that muscle and the adductor magnus and sinks into the deep surface of the semimembranosus below the middle of the thigh. The branches to the adductor magnus enter the muscle at various points in the middle third of the thigh. The disposition of the nerve-bundles in the trunk is correlated with the anatomical disposition of the structures to which they are distributed. That is to say, the sensory bundles occupy the more superficial (posterior) position, while of the more deeply situated motor bundles the nerves eventually distributed to the deeper limb-muscles occupy a deep (anterior) position relatively to those distributed to the more superficial muscles. The same rule applies to the branches given off from the tibial division in the popliteal space. The most superficial nerve here is the tibial communicating (posterior cutaneous nerve of the calf). This nerve not only occupies the central and most posterior position in the popliteal space, but it preserves this position when traced into the tibial trunk. Next in order from the surface towards the back of the knee-joint follow the nerves to the two heads of the gastrocnemius and the plantaris. These three are practically equidistant from the surface of the limb, and in the tibial trunk their corresponding bundles have the same relative position to each other. Next follows the nerve to the soleus, only very slightly

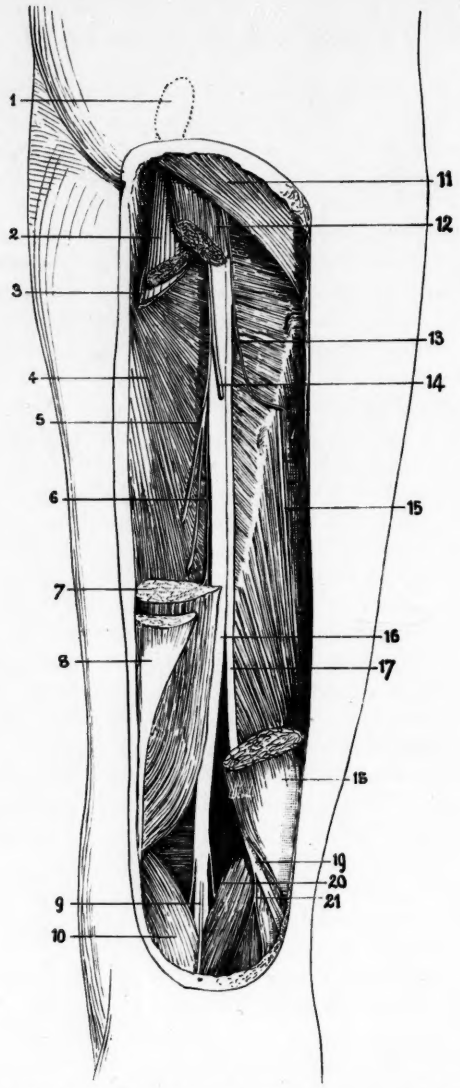

FIG. 1.—General view of the sciatic trunk. Hamstring muscles partly removed.

1, Tuber ischii; 2, semitendinosus; 3, semimembranosus; 4, adductor magnus; 5, nerve to the adductor magnus, partly covered by the nerve to the semitendinosus which has been cut short; 6, nerve to the semimembranosus; 7, semimembranosus; 8, semitendinosus; 9, tibial communicating nerve (posterior cutaneous nerve of the calf); 10, inner head of gastrocnemius; 11, gluteus maximus; 12, biceps femoris, ischial head; 13, nerve to femoral head of biceps; 14, nerve to ischial head of biceps; 15, femoral head of biceps; 16, tibial trunk; 17, common peroneal trunk; 18, biceps; 19, common peroneal trunk lying upon plantaris and outer head of gastrocnemius; 20, plantaris; 21, lateral cutaneous nerve of the calf.

deeper than the nerve to the outer head of the gastrocnemius (fig. 2). To the inner side of the nerve to the popliteus and almost the same distance from the surface is the posterior tibial nerve. It will be shown later that the bundles as seen upon a cross-section of the tibial trunk are approximately in the same relative position as the nerves derived from these bundles. In the case of the common peroneal nerve this applies also, but in a modified degree. As the nerve passes round the neck of the fibula, it has the form of a flattened band. This band can be seen to consist of two parts, antero-superior and postero-inferior. The former is the anterior tibial nerve (deep peroneal), the latter is the musculo-cutaneous (superficial peroneal). Lying between the two is the nerve to the peroneus longus. In some cases the small articular branch to the knee-joint can also be seen lying in front of the anterior tibial. Further proximally, in the outer part of the popliteal space, the common peroneal nerve gives off its cutaneous branches, the lateral cutaneous and peroneal communicating.

Naked-Eye Appearance of the Sciatic Trunk.

The trunk is enclosed in a firm sheath which varies in thickness and transparency in different subjects. Loose areolar tissue fills the space between the surrounding muscles and the nerve-trunk. In this tissue ramify vessels derived from the perforating branches of the profunda femoris artery. In the upper part of the posterior region of the thigh, several other branches derived from the inferior gluteal artery pass downwards in relation to the sheath of the sciatic trunk; and a few twigs from the internal circumflex artery reach the nerve. Of these vessels only two appear to have any fairly constant relation to the sciatic sheath. These are branches of the sciatic (inferior gluteal) artery. In several of the subjects examined, these two vessels were found to leave the sciatic artery immediately below the pyriformis and to proceed downwards upon the sheath as it covers the posterior surface of the sciatic trunk. The two arteries run parallel with each other, and parallel also with the inner and outer borders of the nerve-trunk, in such a manner as to divide the posterior surface of the trunk into three equal columns.

In cases where the tibial and common peroneal trunks are enclosed in a common sheath, the posterior surface of the sciatic trunk is divided into a large median and a smaller lateral column by a furrow. This furrow represents the line of division between the tibial and common peroneal trunks. It is occupied by an antero-posterior septum which blends in front and behind with the common fibrous sheath. The furrow is usually distinct enough to be visible through the sheath. In some cases the furrow

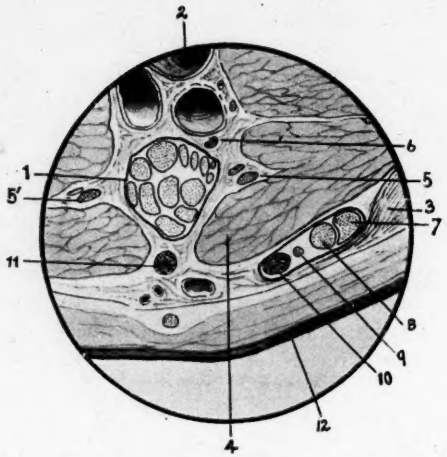

FIG. 2.—Transverse section through right fœtal leg at level of upper end of tibial diaphysis.

1, Tibial trunk; 2, popliteal vessels; 3, biceps; 4, gastrocnemius, outer head; 5, nerve to outer head of gastrocnemius; 5', nerve to inner head; 6, nerve to popliteus—between this and the nerve to the outer head of gastrocnemius is seen the nerve to the soleus; 7, anterior tibial bundle (deep peroneal); 8, musculo-cutaneous bundle (superficial peroneal); 9, branch to peroneus longus; 10, peroneal cutaneous bundle; 11, tibial cutaneous bundle (posterior cutaneous nerve of the calf); 12, skin.

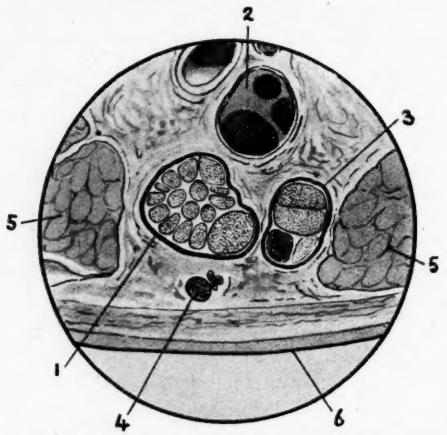

FIG. 3.—Section through middle of popliteal space. Same limb as fig. 2.

1, Tibial trunk; 2, popliteal vessels; 3, common peroneal trunk, showing peroneal cutaneous bundle (dark) postero-internally, anterior tibial anteriorly, and musculo-cutaneous bundle between the two; 4, tibial cutaneous bundle; 5, gastrocnemius; 6, skin.

is filled up with fat, and a yellowish line is then seen marking the cleft between the two nerve-trunks. Distally the furrow lies at the junction of the outer with the middle third of the sciatic trunk. At the proximal end it is situated rather nearer the outer border; and it will be observed that the outer one of the two longitudinal arteries above mentioned lies either in the furrow itself or immediately to the inner side of it. Occasionally one or two other blood-vessels are found passing obliquely through the interval between the tibial and common peroneal trunks, thereby helping further to distinguish the one from the other. When the whole trunk lies exposed in a dissection, it is easy to split the sciatic trunk into its two main divisions by pulling apart the tibial and peroneal trunks from below upwards. But it is by no means always easy to find the exact plane of division if only a short piece of the nerve is seen at the bottom of an operation wound. The surface of the nerve may present such a perfectly uniform appearance, especially in its proximal part, that measurement must be relied upon. Distally the inner two-thirds and proximally the inner five-eighths of the posterior surface of the sciatic trunk may be regarded as belonging to the tibial, the remainder to the common peroneal trunk. Unfortunately, the two longitudinal vessels are only traceable for three or four inches, and by the time the sciatic trunk has emerged from beneath the gluteus maximus they are so much reduced in size as to be practically useless as guides. These vessels are shown in section in figs. 4 and 5.

Not until the enveloping fibrous sheath is opened can the nerve-bundles be distinctly seen. It then becomes evident that both divisions of the sciatic trunk show several parallel longitudinal markings which represent the various nerve-bundles separated from each other by the perineurium. Distally the bundles become directly continuous with the branches given off from the sciatic trunk. Here also the perineurial sheaths appear to be less firmly connected with each other than they are in the trunk higher up. For an inch or two the nerves can be readily followed upwards into the trunk. More proximally the process of splitting becomes difficult. The difficulty is partly due to the more intimate connection between the perineurium of one bundle and that of its neighbours, partly because branching takes place. It will be useful here to anticipate by stating that the central parts of both tibial and peroneal trunks are in part occupied by a plexus. The plexus nowhere comes to the surface, being everywhere covered by the longitudinal bundles seen upon the surface. The fibres which form the plexus are derived from branches split off from the deeper aspects of many of the bundles. The plexus is not equally well marked throughout the trunk. It occupies chiefly the middle third. The distal

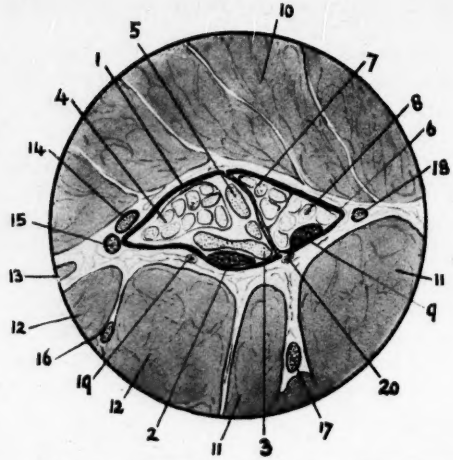

FIG. 4.—Transverse section through middle of thigh. Same limb as the foregoing figure.

1, Tibial trunk; 2, tibial cutaneous bundle; 3, gastrocnemius and soleus bundle; 4, posterior tibial bundle; 5, popliteus and plantaris bundles; 6, common peroneal trunk; 7, anterior tibial bundle; 8, musculo-cutaneous bundle; 9, peroneal cutaneous bundle; 10, adductor magnus; 11, biceps; 12, semitendinosus; 13, semimembranosus tendon; 14, 15, 16, 17, 18, nerves to adductor magnus, semimembranosus, semitendinosus, biceps (ischial head), and biceps (femoral head) respectively; 19, 20, branches of sciatic artery descending upon the sheath of the sciatic trunk.

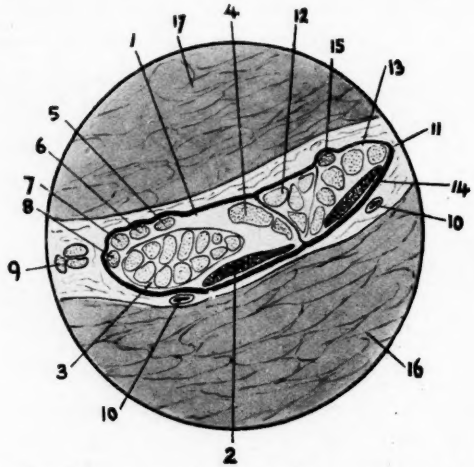

FIG. 5.—Transverse section through proximal part of thigh. Same subject as foregoing sections.

1, Tibial trunk; 2, tibial cutaneous bundle, flattened; 3, posterior tibial bundle; 4, popliteus and plantaris bundle; 5, nerve to adductor magnus; 6, nerve to semimembranosus; 7, nerve to semitendinosus; 8, nerve to biceps (ischial head)—these four nerves here lie within the sheath of the tibial trunk, upon the anterior (deep) surface of the posterior tibial bundle; 9, small sciatic nerve (posterior cutaneous nerve of the thigh); 10, branches of sciatic artery; 11, common peroneal trunk; 12, anterior tibial bundle; 13, musculo-cutaneous bundle; 14, peroneal cutaneous bundle flattened; 15, nerve to the femoral head of biceps within the sheath of common peroneal trunk; 16, adductor magnus; 17, gluteus maximus.

third is altogether free from branchings, the proximal third almost free. If the trunk be dissected without injuring any of the bundles, it is easy to split up the whole thickness of the distal third into its component bundles. The proximal third can be treated in the same way with almost equal ease. But in the middle third only the superficial bundles can be readily lifted out of their beds. When this is done, the branching fibres will be seen leaving the deep surface of each bundle. To display the plexus it is necessary to free all these branches from surrounding connective tissue. It will then be seen that the plexus is most complicated in the centre, less so at either end. At the proximal end the network becomes simplified by the reunion of fibres emerging from and entering into the plexus. The finer meshes of the plexus are gradually gathered up into strands which become continuous with the superficial bundles above the proximal end of the plexus. The plexus affords numerous facilities for the rearrangement of fibres, and the elements composing any given bundle are by no means necessarily the same below the plexus as they are above it. It is probable that most of the fibres composing a bundle pass over to other bundles and that they are replaced by fibres entering the bundle from elsewhere. Some bundles give off a larger number of fibres than they receive, and these diminish in size from above downwards. Other bundles show the opposite arrangement. The tibial communicating and peroneal communicating bundles probably undergo least change in composition. Their upward prolongations certainly show least tendency to branching. In ten out of the twelve cases examined, no branches at all were found. In the other two cases the tibial communicating bundle sent two branches upwards into the gastrocnemius bundle.

Arrangement and Position of the Nerve-Bundles.

It will be convenient to trace first the course of the *cutaneous bundles* derived from the tibial communicating, peroneal communicating, and lateral cutaneous nerves of the calf.

The tibial communicating nerve (posterior cutaneous nerve of the calf).—The part of this nerve which lies free in the popliteal space is circular on section. The bundle belonging to it lies as a somewhat flattened band upon the centre of the posterior surface of the tibial trunk, and covers rather less than the middle third of the latter. When traced upwards, the bundle very gradually inclines outwards towards the lateral border of the tibial trunk, which, however, it does not actually reach. In the lowest part of the trunk this bundle therefore lies equidistant between the two borders of the trunk. At the proximal end it covers the outer third or a

little more of the trunk, with a narrow bundle just visible to its outer side, lying in touch with the septum between the tibial and common peroneal trunks. This condition existed in all the cases examined except two fœtal ones, in which the tibial and peroneal cutaneous bundles approached each other centripetally, and in the proximal third were only separated by the septum. The tibial communicating bundle broadens slightly as it approaches the proximal end of the sciatic trunk, so that more surface is here covered by it than is the case distally. This broadening is not due to an addition of fibres. None enter or leave the bundle, and it is easy to separate the bundle from the trunk. This was impossible only in the two cases just mentioned, in which there were two slender branches running upwards and outwards from the tibial communicating nerve to join the outer gastrocnemius bundle.

The peroneal cutaneous bundle. — In this are included the lateral cutaneous nerve of the leg and the peroneal communicating nerve. These nerves leave the common peroneal trunk on its postero-internal aspect. When traced upwards upon the peroneal trunk, this bundle is seen to incline gradually outwards in the same way and almost to the same degree as the tibial communicating nerve. In most of the cases examined, the peroneal cutaneous bundle also became flatter and broader proximally, and covered rather less than the outer half of the common peroneal trunk at its proximal end. This bundle therefore crosses the posterior surface of the common peroneal trunk diagonally from the inner side below to the outer side above.

Having traced the two cutaneous bundles, and bearing in mind the areas which lie on either side of them, it will be easier to follow the course of the other bundles found in these areas.

Common Peroneal Trunk.

This trunk can be divided up into four bundles. Besides the peroneal cutaneous bundle just described, there are anterior tibial (deep peroneal), musculo-cutaneous (superficial peroneal), and the bundle formed by the branch to the peroneus longus muscle. In the popliteal space the trunk is oblong on section, and these bundles lie side by side. The anterior tibial lies outermost, the musculo-cutaneous next, then the small nerve to the peroneus longus, and, most internally, the peroneal cutaneous bundle. A short distance below the point at which the tibial and common peroneal trunks come in contact, the peroneal trunk is no longer oblong, but becomes circular on section. More proximally still, the inner side of the peroneal trunk becomes flattened against the outer side of the tibial trunk. But

the septum runs forwards and inwards, not directly forwards. Therefore the innermost part of the common peroneal comes to lie anterior (deep) to the outermost part of the tibial trunk. In this region the common peroneal trunk has a roughly triangular outline on transverse section (figs. 4 and 5). A section through the upper part of the popliteal space (fig. 3) shows the common peroneal trunk circular on section. The bundles have undergone a slight change in position. The anterior tibial bundle is now in front, the musculo-cutaneous bundle lies immediately behind it, and posteriorly are the peroneal cutaneous bundle and the nerve to the peroneus longus side by side, the muscular bundle to the outer side of the sensory. More proximally where the trunk is triangular on section (figs. 4 and 5) the antero-internal angle is occupied by the anterior tibial bundle, the outer angle by the musculo-cutaneous bundle, the postero-internal angle also by that part of the musculo-cutaneous bundle which is not covered by the peroneal cutaneous bundle. In other words, all the bundles composing the common peroneal trunk are spirally arranged. It may be observed that the nerve to the femoral head of the biceps has a similar disposition. This nerve emerges from the common peroneal trunk upon its anterior surface near the groove between the anterior tibial and musculo-cutaneous bundles. Followed distally the nerve winds round to the outer side of the trunk and finally pierces the sheath at the lateral edge (fig. 4). This nerve leaves the trunk in the region of the tuber ischii, but remains within the sheath till it reaches a point about two inches further down.

The Tibial Trunk.

The most superficial (posterior) branch of the tibial trunk in the popliteal space is the tibial communicating nerve. The bundle of this nerve has been described lying upon the posterior surface of the trunk. Next in order come the nerves to the two heads of the gastrocnemius, and the nerves to the plantaris and soleus. The nerve to the soleus is large, and is given off from the outer side of the tibial trunk a little below the level of the knee-joint. The other three nerves leave the trunk at a slightly higher level. The nerves to the outer head of the gastrocnemius and plantaris come off from the outer side, the nerve to the inner head of the gastrocnemius from the inner side of the trunk. Followed upwards, these nerves are seen to spring from a common bundle, which is situated immediately anterior (deep) to the tibial communicating bundle. In transverse section this bundle for the supply of the calf-muscles is at first dumb-bell shaped, its two thickened borders being occupied by most of the fibres. At a somewhat higher level the section becomes crescentic. In the crescent

the fibres are evenly distributed. The concavity of the crescent faces backwards and is filled by the tibial communicating nerve (fig. 4). This relation remains unchanged throughout the lower half of the trunk. Above this level the motor bundle gradually dwindles, its fibres passing into the plexus. The gastrocnemius and soleus bundle is slightly broader than the overlying sensory bundle, a narrow strip being visible on either side of the sensory bundle. The outer strip (outer gastrocnemius, soleus and plantaris fibres) lies along the septum dividing tibial and common peroneal trunks. Lying also in touch with the septum, but anterior (deep) to the gastrocnemius and soleus bundle, is the nerve to the popliteus. This nerve leaves the tibial trunk upon its antero-external aspect; and the corresponding bundle is seen on transverse section in the antero-external angle of the tibial trunk (figs. 4 and 5). This bundle can be traced upwards into the proximal third of the trunk. The slender plantaris bundle intervenes between it and the gastrocnemius-soleus bundle. The internal two-thirds of the tibial trunk are occupied by the upward extension of the posterior tibial nerve. Transverse sections through various regions show that this large bundle is oblong on section, and that internally it reaches to the inner border of the trunk, while externally it occupies the angle between the popliteal and gastrocnemius-soleus bundles. Proximally, however, the antero-internal part of the posterior tibial bundle is covered by the nerves to the hamstring muscles.

Nerves to the Hamstring Muscles.

These nerves, with the exception of the nerve to the femoral head of the biceps, are given off from the inner side of the tibial trunk. In sections across the proximal end of the trunk four nerves are visible upon the antero-internal surface of the trunk, between the sheath and the posterior tibial bundle. The outermost of these is the nerve to the adductor magnus. Next in order comes the nerve to the semimembranosus, then the nerve to the semitendinosus, and most internal the nerve to the ischial head of the biceps. When traced distally these nerves are seen winding spirally round the inner side of the tibial trunk. The first to appear upon the posterior aspect is the nerve to the biceps. Then follows the nerve to the semitendinosus. The nerve to the semimembranosus remains upon the inner side of the tibial trunk. The nerve to the adductor magnus remains in front of the tibial trunk, but inclines to its inner side. The posterior tibial bundle is therefore in contact both with the anterior and with the posterior part of the sheath, except postero-externally, where it is overlapped by the tibial communicating and gastrocnemius-soleus bundles;

and antero-internally, where its proximal part is overlaid by the nerves to the hamstring muscles and the adductor magnus. It has already been mentioned that the posterior tibial bundle is easy to isolate, being connected only loosely with its neighbours. In several of the cases it was also found that a few blood-vessels lay in the loose areolar tissue surrounding this bundle. These vessels may be of use in locating the posterior tibial bundle.

Summary.

1. In the upper part of the thigh the tibial and common peroneal trunks are applied so closely to each other, that the line of division may escape detection. Yet each trunk is completely separated from the other, enclosed in its own fibrous sheath. The adjacent parts of the two sheaths adhere to each other and form a septum. The septum does not occupy an antero-posterior plane, but passes forwards and inwards between the two trunks, beginning behind at the junction of the outer with the middle third of the posterior surface of the sciatic trunk, and ending in front near the middle line of the anterior surface. In other words, the common peroneal trunk lies along the outer side and rather in front of the tibial.

2. There are no reliable landmarks upon the sheath indicating the position of subjacent nerve-bundles. There are several blood-vessels running upon the sheath, but they are not constant enough to be of service. The sciatic artery sends down a branch to the sciatic trunk. This vessel divides into two branches which run downwards upon the posterior aspect of the sheath. The outer one usually lies in the groove between peroneal and tibial trunks—that is, at the junction of the outer with the middle third. The inner branch of the artery bisects the posterior surface of the tibial trunk. These vessels are only two or three inches long, and do not reach further than the lower edge of the gluteus maximus. One or two vessels may sometimes be seen piercing the sciatic trunk along the line of the septum.

3. The level at which each nerve leaves the trunk varies to some extent. The nerves to the hamstring muscles emerge from the sheath one or two inches distal to the ischial tuberosity. The nerves to the gastrocnemius, soleus, and plantaris arise near the centre of the popliteal space, the nerve to the popliteus more distally, and the branches to the flexor longus digitorum, flexor longus hallucis, and tibialis posticus at the lower end of the popliteal space. It is not possible to recognise each nerve merely by the level at which it leaves the trunk. More constant than its origin is the relation which each nerve has to neighbouring nerves and to the trunk from which it arises. There is no haphazard grouping of the nerves or

their bundles in the trunks, but a definite arrangement depending upon the relative position of the soft parts. In the case of muscular branches the nerves run as directly as possible from the points of exit from the nerve-trunk to the points of entrance into their respective muscles.

4. Both tibial and common peroneal trunks contain a plexus involving in each case the central part of the middle third. Distal to the plexuses the trunks are made up of unbranched bundles. In the proximal third there is little or no plexiform arrangement. The plexuses are overlaid by a layer of longitudinal bundles forming the direct, unbranched upward prolongations of the several nerves given off from the trunks below the plexuses. On the surface there is no indication of a plexus. Distal to the plexus the bundles are identical with the nerves emanating from them. Proximal to the plexus these bundles, although superficially continuous with the nerves below, have partly lost their identity through interchange of fibres. The posterior tibial bundle appears to be only slightly connected with the plexus of the tibial trunk. The other bundles, with the exception of the two sensory ones, are extensively involved in the plexuses. The plexuses may be supposed to be largely, if not entirely, composed of motor fibres. The purely cutaneous bundles have little or no connexion with the plexuses. What relation the mixed nerves have to the plexuses it is impossible to say until the sensory have been separated from the motor bundles. One of the functions of the plexuses in the nerve trunks may be to supply to each muscle several routes by which impulses may reach it. In case one route becomes blocked, several others are still available. There is no doubt that a nerve trunk may be partly divided without producing any perceptible disturbance of function in the motor nerves arising from the nerve trunk distal to the seat of injury.

5. A variable but considerable portion of the posterior surfaces of the tibial and common peroneal trunks is covered by sensory fibres. These are grouped in two bundles, one associated with each division of the sciatic trunk. These bundles are superficial throughout. They are not connected with the plexuses, or only to a slight extent. In one instance it was found that the tibial sensory bundle sent two fine branches upwards and outwards into the outer gastrocnemius bundle. The tibial sensory bundle lies in the middle line of the tibial trunk distally. Proximally it inclines slightly outwards. The same course is pursued by the peroneal sensory bundle. Distally this bundle is situated upon the posterior surface of the common peroneal trunk, and slightly to the inner side. Proximally the bundle is still behind, but has gradually gained the outer aspect of the trunk. This change of position on the part of the peroneal sensory bundle is associated with the general spiral arrangement of the other

peroneal bundles. In the tibial trunk the slightly oblique course of the tibial sensory bundle is independent of the direction of the other tibial bundles. The latter are practically vertical throughout.

6. The twisting of the nerve trunks, shown decidedly in the peroneal trunk, less so in the tibial, points probably—but not absolutely—to the twisting which the limb is believed to undergo during development. Of all the structures of the limbs which might be expected to show evidence of such rotation, none would be more likely to do so than the nerves.

7. The origin of the nerve to the femoral head of the biceps from the anterior (deep) surface of the common peroneal trunk is consistent with the generally accepted view that this muscle is an extensor derivative functioning as a flexor.

8. The relative position of the tibial and common peroneal trunks is correlated with their flexor and extensor distributions, *i.e.* the tibial towards the ventral side of the limb, the peroneal towards the dorsal side. The common peroneal trunk tends to lie upon the anterior as well as upon the outer side of the tibial.

9. The nerves to the hamstring muscles leave the sciatic trunk proximal to the plexuses described above. None of these nerves are connected with the plexuses. The dissection of the proximal parts of the sciatic trunks was not completed. As far as it went, the examination of this part of the trunk suggested the presence of a smaller plexus formed by a branching of the nerves supplying the hamstring muscles.

10. The vascularity of the sheath of the posterior tibial bundle may be of service in differentiating this bundle from neighbouring ones. The fact that this bundle survives injuries more readily than some of the others may be taken as clinical evidence of its richer blood supply, and also, perhaps, of its looser sheath.

I cannot close this part of the work without expressing my sincere thanks to Professor Barclay Smith for his kindness in supplying me with material from the Anatomical Department at King's College; for many most interesting and valuable suggestions; and, most of all, for his unlimited care and patience in repeatedly going over the subject of this paper with me.

THE GENITALIA OF TUPAIA.

By FREDERIC WOOD JONES, *Professor of Anatomy in the University of London; The London School of Medicine for Women.*

MATERIAL.

THE species that I have dissected is *Tupaia ferruginea*; it is the one that is especially entitled to the native name "tupai tanah" in the Straits Settlements.

I have had the opportunity of dissecting two specimens, a male and a female, both of them fully adult. The condition of these two examples, which were preserved in spirit, is such that every confidence may be placed in the normal appearance of the parts described. The preservation rendered histological examination of the tissues quite satisfactory. For the use of this material I am indebted to the kindness of Dr Foster Cooper and Professor G. Elliot Smith. The specimens formed part of the collection of the Survey of the Vertebrate Fauna of the Malay Peninsula undertaken by the Federated Malay States Museum, and they were taken at Kuala Lumpur.

REPRODUCTION.

Tupaia ferruginea lives as a rule in pairs or as solitary individuals (Cantor); it does not associate in groups, a family party being the limit of community.

From one to three young are produced at a birth. Cantor describes the birth of a single offspring as the most usual occurrence with *T. ferruginea*; but Boden Kloss regards two as constituting a normal litter. Lyon gives a list of embryos examined in pregnant females, and in one case there were three present, but in others only one or two.

The birth of two young would seem to be the rule with *T. belangeri*, one with *T. nicobarica*, and as many as four with *T. chinensis* (Lyon).

The nesting habits of the Tupaiadæ have been described by a few observers. Boden Kloss has described the nest of *T. ferruginea*, which is placed in holes in trees or even in fallen stumps.

The nest of *T. chinensis* has been found in a hollow bamboo (Lyon).

Charles Hose has recorded the nesting of *T. minor* in Borneo: "It breeds in a nest in an old stump covered with creepers, but I am not sure

whether it makes the nest itself or occupies the nest of a bird. I have found two of these nests, but the material used was different."

I know of no observations upon the condition of the young at birth, nor upon the length of stay in the nest and the period of suckling. Breeding seems to take place throughout the year, but no observations appear to have been recorded upon the duration of gestation.

Reproductive System.

In a paper entitled "The Anatomy of *Tupaia*," Garrod made some slight notes upon the internal genitalia of the male *T. belangeri* in 1878.

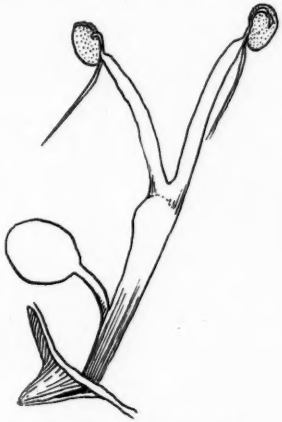

Fig. 1.—*Tupaia ferruginea.* Internal genitalia of adult female.

Fig. 2.—*Tupaia ferruginea.* Internal genitalia of adult female seen in section.

In 1914, Pehrson, in describing the ossicle in the clitoris of some Primates and Insectivores, makes brief mention of the condition of this structure in the female *T. javanica*. With the exception of these papers, I have, so far, encountered no published work upon the reproductive system of the Tupaias.

Female (see figs. 1 and 2).—The ovary was extremely small in my specimen; it was surrounded by a partial bursa. The cephalic ovarian ligament is but poorly developed; but the caudal ligament is well defined. The Falloppian tubes are narrow-bored and tortuous, and closely applied to the ovary, the ostium abdominale being within the ovarian capsule. The cornua of the uterus are elongated, and the body of the uterus is

comparatively small. Lyon, who records the number of embryos present in several pregnant females, does not state in what part of the uterus the pregnancy occurs, and it would be interesting to know if there is any specific variation in the site of fœtal lodgment. A well-marked os uteri marks off the lower limits of the uterine cavity from the vagina. The vagina is a roomy thin-walled chamber, and measures 7 mm. from os uteri to urogenital sinus The urogenital sinus is longer than the vagina, and measures 9 mm.: it is distinctly marked off from the vagina above, but

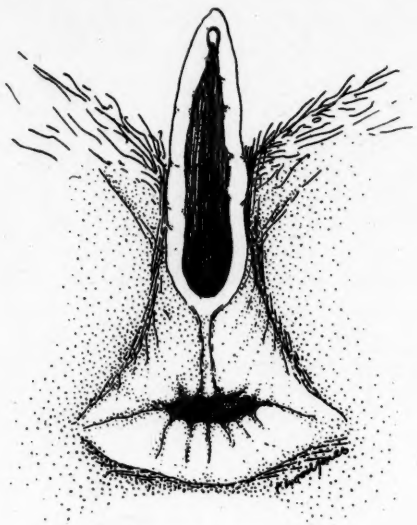

FIG. 3.—*Tupaia ferruginea.* External genitalia of adult female.

in my specimen no structure which can definitely be named a hymen is present below.

The whole urogenital sinus is smooth-walled, and covered with a shining mucous membrane. The urogenital sinus lies behind the elongated pubic symphysis.

The external genitalia of the female (see fig. 3) show several features which are worthy of note. The genital outlet is elongated in an antero-posterior direction, the total length of the orifice being 7 mm. The external genitalia can only be described as prominent. The very considerable extent of the vulval orifice is brought about by the prominence of the genital tubercle, and the structures embryologically associated with it.

The clitoris is free at its extremity, which is small and appears as a median elevation between the two prominent folds (inner genital folds) which, running from it, bound the sides of the vulval orifice and lead to the prominence of the part.

Behind the vulval orifice these inner genital folds meet in a definite commissure and thence proceed across the perineum as a median raphé (4 mm. in length) which terminates at the anal margin. Within the vulva, the mucous membrane is slightly folded in a radiating manner, the ridges upon the surface all converging upon the mouth of the urogenital sinus, which is situated at the extreme posterior limit of the vulva. The urogenital orifice is situated, therefore, very near to the anus, and the perineum is extremely short.

The region around the anus, and upon either side of the inner genital folds, is devoid of the general body hairs; there is, in the spirit specimen, no distinct trace of pigmentation, but sparse specialised sexual hairs are scattered over the whole region.

Male.—The general disposition of the internal genitalia of the male is shown in figs. 4 and 5, and but few points require further emphasis.

The entrance of the genital ducts into the urogenital tract is effected at the very considerable distance of 7 mm. from the site of opening of the ureters. For some considerable distance before they pierce the urethral wall, the genital ducts are in close contact with each other, but although their union is anatomically a very intimate one the tubes remain entirely separate until they open into the urethra.

In this part of their course they have placed upon either side of them, and behind them, bulky bilateral masses, which appear to the naked eye to be faintly subdivided into upper and lower portions. The line of demarcation is, however, but feebly delineated. Upon histological examination the upper portions of these masses prove to be complex vesiculæ seminales, while the lower portions compose the prostate. The prostate is strictly limited to these two postero-lateral masses, there being no gland tissue upon the anterior wall of the urethra, and none corresponding to the human third lobe. The common ejaculatory ducts open into the urethra, entirely separately, upon a slightly marked colliculus seminis, there being no common chamber, or uterus masculinus. The portion of urethra intervening between the site of opening of the genital ducts and the bulb is elongated: it runs behind the symphysis pubis, and measures 13 mm. in my specimen. It is wrapped round by an uninterrupted muscular coat (m. constrictor urethræ), and is enclosed in its entire extent between the two levator ani muscles, which form a muscle sheath common to it and to the lower part of the rectum.

The bulb of the urethra is prominent, the bulbar muscles constituting an exceptionally bulky mass. Two glandular bodies are placed upon either side of the bulbar muscles. The larger mass, situated cephalad, is 7 mm. in its long axis, and is dark yellow in colour. It presents all the histological features of the glandulæ bulbo-urethrales, its ducts open into the bulbar portion of the urethra, and these two bodies are therefore regarded as true Cowper's glands. The smaller mass measures 4 mm. in its long

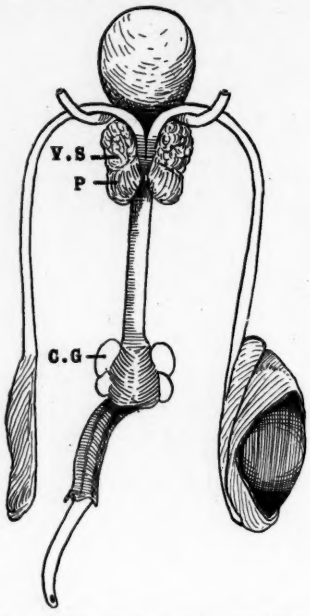

FIG. 4.—*Tupaia ferruginea*. Genitalia of the male viewed from behind.
V.S., vesiculæ seminales; P., prostate; C.G., Cowper's glands.

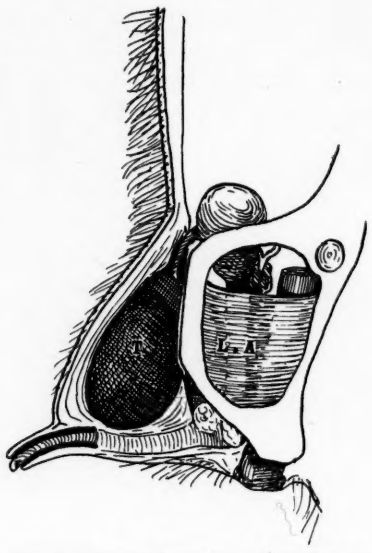

FIG. 5.—*Tupaia ferruginea*. Dissection of the male pelvis from the left side to show the relation of the scrotal pouch to the body of the penis.
T., right testes; L.A., levator ani.

axis; it is pale yellow, and is bound but loosely to the bulb, it being situated, in the undisturbed condition of the parts, in the interval between the rectum and the bulbar musculature. No duct opening of these glands into the urethra could be found in serial sections, and it is therefore most probable that they belong to the class of circumanal scent glands.

In my male specimen there was a very curious disproportion in the relative sizes of the two testes, for while that of the right side was large, measuring 15 mm. in its long axis and 9 mm. in breadth, the left one was

a mere fusiform mass of tissue. Histologically, the left testis appeared to be in a functionless condition, the testicular structure being extremely rudimentary; if this is a pathological feature, or merely a functional phase, I am unable to determine.

The epididymis is well developed. The total length of the right testis including the epididymis was 19 mm.

The tunica vaginalis extended no further than the upper pole of the testis, and no trace of a funicular process could be found, the isolation of the tunica vaginalis being as complete as in Man.

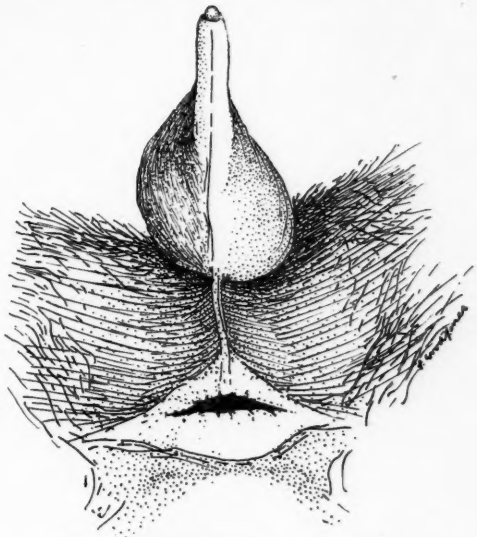

FIG. 6.—*Tupaia ferruginea*. Perineal view of the external genitalia of adult male.

The external genitalia of the male are of the greatest interest (see figs. 6 and 7). The penis is elongated, its total extra-pelvic course being 30 mm., and of this length 10 mm. consists of the fusiform glans. In the undisturbed condition of the parts, the tip of the glans protruded very slightly from the prepuce, the skin of which is finely wrinkled, and of a colour markedly lighter than the skin of the scrotal areas. A few fine down hairs arise from the base of the external surface of the prepuce. Owing to the curious disposition of the scrotal area, the penis, as it appears upon the external surface of the body, is abbreviated: the external surface of the prepuce measuring no more than 5 mm., whilst its internal surface is double that length.

The glans penis is thin and tapering; in the spirit-preserved specimen it is of a pale yellow colour, and is marked by fine transverse wrinkles There are no projections from its surface, nor are there any visible glandular elevations or orifices. The opening of the urethra is sub-terminal and is situated upon the lower surface of the glans, presenting very much the appearance of the eyelet of a catheter. In my specimen no ossicle was present on the penis.

The most striking feature of the external genitalia of the male is the curious cephalic position of the scrotal pouches. Such a site of the scrotal area is unique among Eutherian Mammals. The testes are obviously

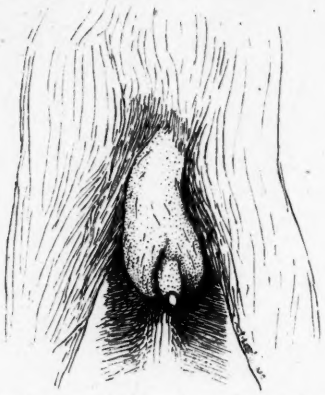

FIG. 7.—*Tupaia ferruginea.* Ventral view of external genitalia of adult male.

permanently descended, and they are lodged beneath skin pouches, having the well-defined characters of the area scroti, which are situated cephalic to the root of the penis. The site of testicular lodgment is not so far forward as it is in the Metatheria; but it occupies a strange position upon the cephalic aspect, and to the sides, of the body of the penis. Perhaps the best description of this peculiarity could be given by likening the scrotal area of the male to the position of the Mons Veneris in the female. In the Metatheria the testes are herniated into scrotal sacs situated cephalic to the site of the Mons Veneris area; in Eutheria, as a rule, into some site caudad of this area; but in *Tupaia* they have lodged within the area, and have depended slightly upon either side of the genital tubercle.

The skin of the scrotum is pigmented, and is considerably darker in colour than the skin of the surrounding districts. It gives rise to scattered hairs which are distinct from the body hair, and it is fine—almost shining—

in texture. There is a well-marked median raphé which extends along the body of the penis across the perineum and to the anal orifice.

Mammary Glands.

The female of *Tupaia ferruginea* possesses four nipples and mammary glands which, in my specimen, are all small and equal in development. They are situated upon the sides of the chest and abdomen as an anterior and a posterior pair. The anterior pair is separated by some 20 mm. from the axilla, and the posterior pair is 20 mm. behind the anterior pair, a slightly smaller interval separating the posterior pair from the region of the groin.

In *T. belangeri* there are three pairs, the additional pair being situated apparently between the thoracic and preinguinal pair of *T. ferruginea*. In *T. nicobarica* there is but one pair, which would appear to occupy the site of the thoracic pair of the other species. I have not examined these species, and I take the statements concerning the number of mammary glands from the paper by Lyon which has been quoted previously.

The Pelvic Symphysis.

The ventral contact area between the two sides of the pelvis extends for a length of 7 mm., and so can only be described as long when the whole proportions of the pelvis are considered. This length of symphysis in so small an arboreal animal, at first sight, seems somewhat anomalous. But it must be remembered that *T. ferruginea* is best described as a bush animal rather than as a thoroughly arboreal one—and by this is implied that it is a haunter of undergrowth rather than of forest trees. The native name "tupai tanah" has regard to this habit, for it means ground squirrel, and is used to distinguish the animal from the true Squirrels, which live in the tree tops. There is a characteristic of this species which I observed in Singapore, that if Squirrels and Tupaias are met in undergrowth, the Squirrels take to the trees when alarmed, but the Tree Shrews make for the ground. Their arboreal activities are well developed, but the tree tops are not their home, nor even the retreat to which they betake themselves in danger. *Tupaia ferruginea* is an arboreal adventurer rather than an elaborated arboreal animal; but it appears, from written accounts, that other Tree Shrews, and especially *Ptilocercus*, have advanced further than this in arboreal life, and I should imagine that in them the area of symphysis would be shorter, and that corresponding differences would be present in the internal genitalia; but I know of no account by which to confirm, or disprove, this supposition.

Placentation.

I have not been able to find any description of the placentation of *Tupaia*, but it seems reasonable to assume, as apparently zoological authorities do, that it is of the type usual among the Insectivora. This assumption is the more justified since Lyon records the condition of several pregnant females without making any note upon the embryo, membranes, or placenta.

Summary and Conclusions.

The genitalia of this animal exhibit an extraordinary blend of characters, since combined with features which are distinctly reminiscent of the Metatheria are conditions which find their exact parallels in the Primates.

In the internal genitalia, the length of the urogenital sinus in the female is correlated with the length of the wrongly-named "membranous portion of the urethra" in the male; and both features, I imagine, are the direct result of the length of the ventral pelvic symphysis.

Concerning the external genitalia, there can be no doubt that development has taken place by cloacal outfolding. The main features of the external genitalia may be summed up by saying that the female condition is singularly like that seen in many Primates, and that the male has several features which are found again in the higher Primates, combined with a scrotal disposition which seems obviously a transition phase from a Metatherian stage.

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THE INTERNAL STRUCTURE OF THE SPHENOIDAL SINUS.

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THE internal structure of the sphenoidal sinus varies greatly in different skulls and on opposite sides of the same skull, and the great differences observed may be responsible for the total lack of any previous attempt to determine the arrangement and significance of the ridges and septa which are frequently found therein. Examination of a large number of sinuses (292 belonging to 180 skulls) reveals the fact that, though it is rare to find

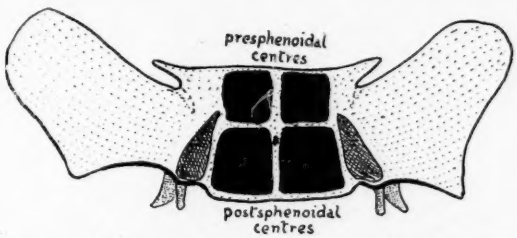

FIG. 1.—A scheme to show the centres concerned in the formation of the sphenoidal sinus. Body centres black, centres for lingulæ cross-hatched.

two sinuses exactly alike, there are certain features which recur with such regularity as to enable us to bring a certain amount of order out of seeming disorderly chance-variations.

Before indicating these features we must prepare the way by a brief consideration of a few points relative to the development of the sinus.

The body of the sphenoid is developed from four symmetrically placed bony nuclei, two pre-sphenoidal centres in front and two basi- or post-sphenoidal centres behind. The cartilage between the pre- and post-sphenoidal portions disappears either shortly before or soon after birth; in a sagittal section the line representing its position begins above near the olivary eminence and extends obliquely downwards so that the section of the pre-sphenoidal area approaches the triangular rather than the quadrilateral shape. Along each side of the post-sphenoid area the bone is formed from the lingulal centres. Each lingulal centre leads to the formation of

a triangular portion of bone with a small base posteriorly (corresponding to groove for the internal carotid artery) and a thin tapering portion which ends in an acute angle opposite the posterior end of the pre-sphenoid. The major part of the lateral aspect of the pre-sphenoid is in contact with the bone formed from the great wing of the sphenoid. The lingulal area unites with the body of the sphenoid before birth, but the fusion takes place from above downwards, and for some little time after birth indications of the groove between body and lingula can be seen (see fig. 2). The lingula unites with the great wing at a later date after birth.

The sphenoidal sinus is developed primarily at the expense of that portion of the bone formed from the pre-sphenoidal nucleus. During

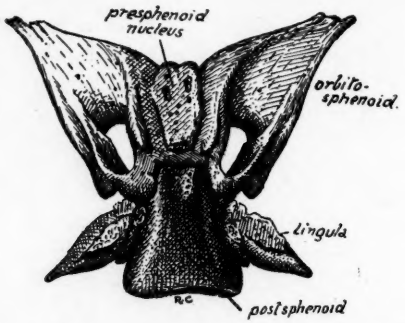

FIG. 2.—Under surface of sphenoid at birth (alisphenoid not present), to show incomplete fusion between linguæ and body centres.

childhood this area becomes almost completely hollowed out, but an antero-posterior septum remains between the two sinuses, and the burrowing air-cavity still respects the boundaries of the areas developed from the nuclei of the post-sphenoid, the lingula, and the great wing. This condition may persist until adult life, but as a rule some time between puberty and adult age the sinus extends backwards or sideways or in both directions. Now there is evidence to show that the bone formed at the line of fusion of two bony centres may be, and often is, of a denser and more resistant nature than the tissue on either side of that line. This fact would account for the restriction of the sinus to the pre-sphenoid during childhood, and would offer an explanation for the frequent incomplete destruction of some of these fusion-barriers by the increased growth-activity of puberty. We hope to show that there are often present in the sinus ridges, crests, or partial septa indicating the position of the lines of fusion between the areas

of bone formed from the nuclei of the pre-sphenoid, post-sphenoid, the lingula and great wing.

When once the barrier between the pre- and post-sphenoid is penetrated, growth is rapid, so that the sinus which first penetrates has the advantage over that of the opposite side, and usurps some of the space which by right should belong to its neighbour. Sometimes, indeed, the sinus of one side fails to break into the post-sphenoidal area, and the other sinus may then occupy three parts of the sphenoidal body. More commonly the struggle

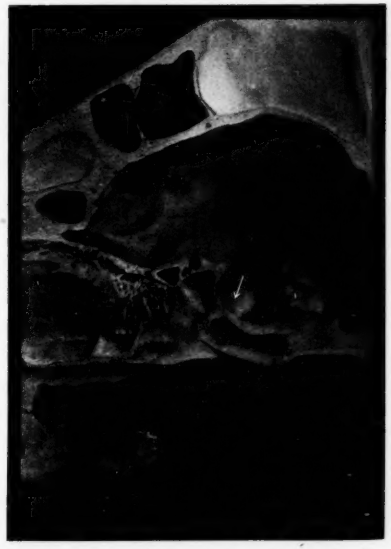

FIG. 3.—Sagittal section of skull of pig, to show synarthrodial joint between pre- and post-sphenoid. (Specimen in R.C.S. Museum, London.)

for the possession of the post-sphenoid results in the deviation of the posterior part of the main inter-sphenoidal septum to one or other side of the mid-line.

If we examine the skull of a pig we gain some help towards understanding the structure and development of the sphenoidal sinus. In the pig there is a synarthrodial joint between the pre-sphenoid and the post-sphenoid. The sinus pushes back through this joint, but the opening made is small, and even after the post-sphenoid has been excavated there remain well-marked medial and lateral elements of the septum between the pre- and post-sphenoid.

Consideration of the mode of development will show that for the sinus to extend laterally to any appreciable extent it must break through either the fusion-barrier between the body and great wing in front or that between the body and lingula behind. But lateral extension is more difficult behind because of the additional fusion-barrier between the lingula and great wing. We should therefore expect that the sinus would more frequently break through into the great wing anteriorly. Observation shows this to be the case, for, though the sinus in a considerable number of cases never bursts out of the body of the sphenoid, when a lateral recess is present it communicates with the main part of the sinus through an opening corresponding to the lateral aspect of the pre-sphenoid, and is separated from the posterior part of the sinus by an incomplete antero-

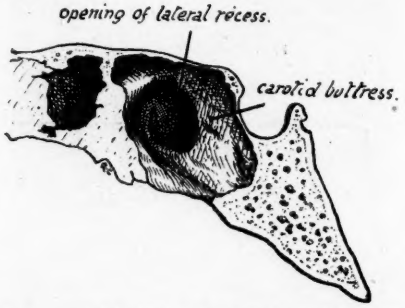

FIG. 4.—Sagittal section of sphenoid, showing opening into lateral recess in front of carotid buttress.

posterior septum corresponding to the fusion-line between the post-sphenoid and lingula or the lingula and great wing.

Sometimes the posterior ethmoidal cells push back into the pre-sphenoidal area and overlap the sphenoidal sinus, but I have never yet seen a specimen in which the ethmoidal cell had succeeded in penetrating the post-sphenoid area; the septum of bone separating the ethmoid and sphenoidal sinuses in these cases corresponds in position to the pre-post-sphenoidal fusion-line.

Sphenoidal sinuses may usefully be classified, according to the amount of their extension backwards, into (*a*) pre-sphenoidal sinuses which are confined to the pre-sphenoid; (*b*) post-sphenoidal sinuses which extend back almost to the clivus; and (*c*) sinuses of an intermediate size in which the post-sphenoid is only slightly encroached upon. Of the 292 sinuses which I examined, 155 were post-sphenoidal, 72 pre-sphenoidal, and 65 intermediate in type. It is quite clear that in a sinus confined to the pre-sphenoid there

are not likely to be any septa apart from the lamella which separates the right sinus from the left, so that the following account of the internal structure refers for the most part to the sinuses of the post-sphenoidal and intermediate types.

We will consider the internal structure of the sinus under the following heads:—

1. Inter-sphenoidal septum.
2. Transverse sphenoidal septum (trans-sphenoidal).
3. Carotid buttress.
4. Recesses from the main sinus.
5. Bulges into the sinus.

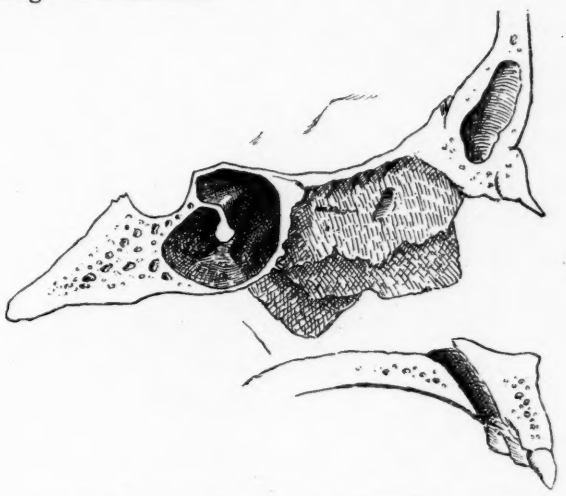

FIG. 5.—Sphenoidal sinus, showing trans-sphenoidal septum.

1. The pre-sphenoidal portion of the inter-sphenoidal septum is usually median in position and antero-posterior in direction. It is not uncommon, however, for it to be slightly to one or other side of the median line. The post-sphenoidal portion of the septum more commonly deviates from the middle line, and sometimes bends almost at right angles to the anterior part so as to form the posterior wall of the opposite sinus. Quite a common attachment posteriorly is to a point corresponding to the situation of the internal carotid artery, so that if the surgeon relied on the septum to guide him to the pituitary fossa he would frequently make a serious mistake.

2. The "trans-sphenoidal septum" is the name best suited to express the

remaining portion of the barrier between the pre- and post-sphenoid. If the element is small, the term "trans-sphenoidal crest" or "ridge" may be used. The common position for this ridge is in the roof of the sinus just behind the level of the olivary eminence or tuberculum sellæ. More rarely the ridge will be found on the floor of the sinus. When the unabsorbed part of the septum is that section attached to the lateral wall, it forms a buttress for the carotid artery, and will be described under that heading. The crest on the roof of the sinus is to be found in about a fourth or a fifth of all sinuses. Much more rarely that part of the septum attached to the floor of the sinus persists, so that we have some ground for concluding that the growing air-cell penetrates first into the lower part of the post-

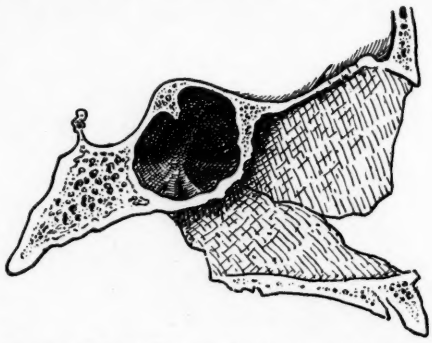

FIG. 6.—Sphenoidal sinus, showing trans-sphenoidal ridge and carotid buttress formed by lateral part of trans-sphenoidal element.

sphenoid. Sometimes the crest is present on both sides, but quite commonly only in the sinus of one side.

3. In skulls in which the sinus does not extend so far laterally the internal carotid artery is supported by the lingula and the lateral wall of the sphenoidal body; but in addition it may have other supports, and when lateral extension takes place there is need of some supporting process if the artery is not to encroach on the sinus. I have applied the term "carotid buttress" to the various special supports which prop up the roof of the sinus in the region of the carotid bulge. The carotid buttress may be derived from different elements:—

(*a*) It may be formed by the lateral portion of the trans-sphenoidal septum. In this case it will be found as a vertical ridge or partial septum with the free edge directed transversely towards the inter-sphenoidal septum.

(*b*) The buttress may be derived from the median part of the trans-

sphenoidal septum. In such a case, which is much rarer than the first variety, it is attached to the inter-sphenoidal septum, and the free crescentic edge extends across the sinus like part of a Gothic arch.

(*c*) The third type of buttress is found in those sinuses with a lateral extension into the lingula and great wing. It consists in an antero-posterior septum attached posteriorly and with a free crescentic edge in

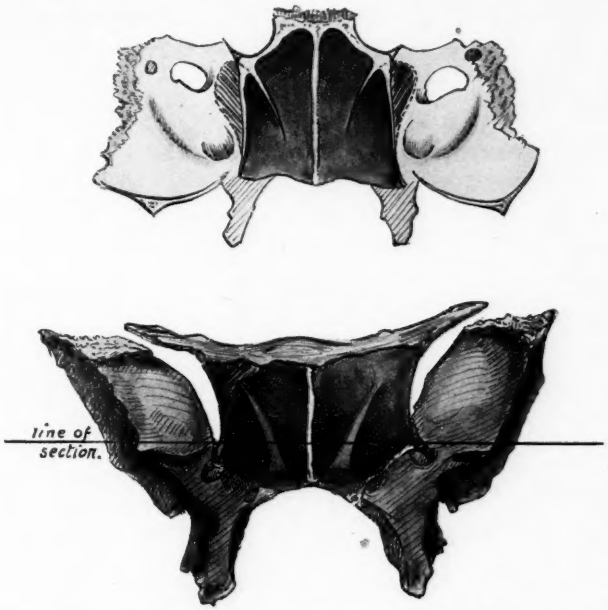

FIG. 7.—Sphenoid opened from the front to show antero-posterior type of carotid buttress. The upper figure is the upper aspect of lower part of bone divided at level of line.

front. It corresponds in position with the line of junction of the body of the sphenoid and the lingula, or in some cases possibly with the line between the lingula and great wing. External to this buttress is the lateral recess.

(*d*) Sometimes the posterior attachment of the inter-sphenoid septum is opposite the carotid bulge, and therefore a deviated septum should be regarded as an occasional carotid support or buttress.

In the pre-sphenoidal type of sinus one may often see a posterior ridge indicating the anterior end of the fusion-line between the body of the sphenoid and the lingula.

4. *Recesses from the main sinus.*—The fully developed sinus may confine itself to the body of the sphenoid, but more frequently there are extensions laterally, forwards or backwards.

The lateral recess extends outwards from the side of the body of the sphenoid into the great wing and lingula. I found a well-marked lateral recess in 72 cases out of 292 sinuses examined. Many others in which the septum between the body and lingula was not present should be included if we wish to estimate the relative frequency with which the sinus extends laterally from the body. The lateral recess is bounded medially by the antero-posterior carotid buttress when present, and laterally reaches out to a variable extent, frequently as far as the maxillary nerve, and rarely travelling through the pterygoid process to the surface of the skull below the infra-temporal crest. I have seen several specimens of the last-mentioned variety in human skulls—a fact of interest in that it is the normal condition in the gorilla and chimpanzee. Under the floor of the lateral recess lies the Vidian nerve, and above its roof are the carotid artery and cavernous sinus.

The anterior recess is not so frequently present. It was noted in 13 cases of the series examined, *i.e.* 5 per cent. It extends forwards, outwards, and slightly downwards from the region below the optic nerve, and usurps the position usually occupied by the posterior ethmoidal cells and cell of orbital process of palate, with which it has no communication. In 2 or 3 per cent. of all sinuses the anterior recess is in relationship with the postero-superior wall of the maxillary antrum, from which it may be separated by a transparent shell of bone.

Very rarely a backward prolongation of the sinus into the basi-occipital may merit the name of a posterior recess. There is sometimes a shallow sub-optic recess beneath the prominence caused by the optic nerve, and more rarely an extension into the lesser wing and anterior clinoid process above the optic nerve constituting a supra-optic recess.

We may here with advantage enumerate the various forms which the ground-plan of the sinus assumes. The accompanying diagrams (fig. 8) represent sections through the sinus parallel to its floor. Dotted lines indicate the junction between pre-sphenoid, post-sphenoid, lingula, and great wing; the outline of the triangular lingulal area is thus clearly indicated.

1 and 2 show simple pre-sphenoidal and post-sphenoidal types respectively. 3 shows pre-sphenoidal sinuses with small lateral recesses. In 4 the lateral recess is well marked, and the antero-posterior carotid buttress is shown. 5 indicates a common type, in which the sinus of one side occupies the whole of the post-sphenoid. 6 is a rare form, which I have only seen once or twice, in which the sinus of one side has extended so far across as to

form a lateral recess on the opposite side; ridges corresponding to the post-sphenoid-lingula line were clearly seen in this case. 7 is the ground-plan of a pair of sinuses with lateral and anterior recesses. 8 shows a condition which is unique in the series I have examined; in it the sinus apparently was unable to break through the region of the trans-sphenoidal septum, and so on the right side it forced its way from the pre-sphenoid out into the great wing and then entered and hollowed out the post-sphenoid from its lateral aspect. The front part of this specimen was missing.

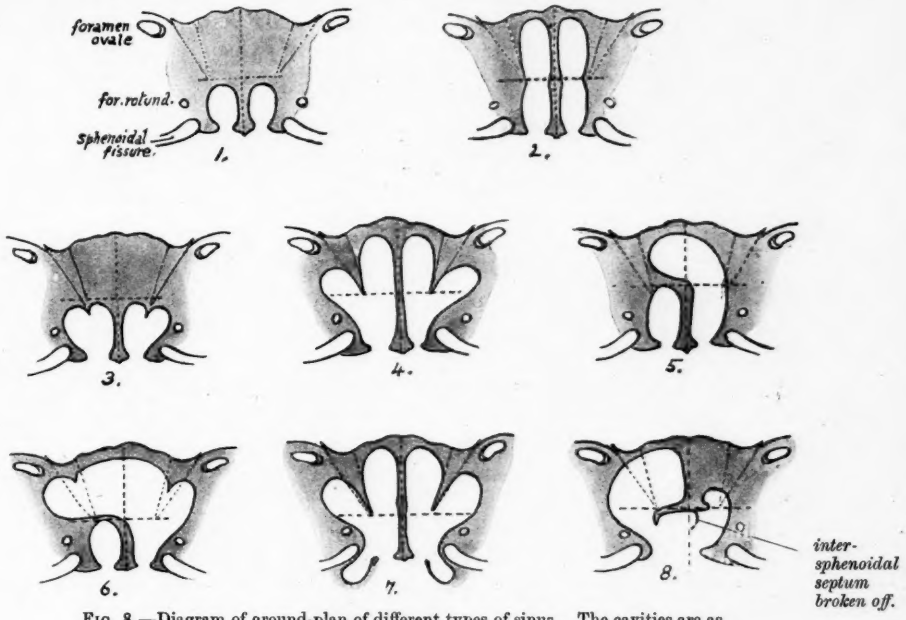

FIG. 8.—Diagram of ground-plan of different types of sinus. The cavities are as they would be seen from above.

5. *Bulges into the sinus.*—The following bulges, caused for the most part by vessels and nerves, may be seen in the walls of the sphenoidal air sinuses:—

(1) Pituitary.
(2) Carotid.
(3) Optic.
(4) Vidian } in the lateral recess.
(5) Maxillary }
(6) Spheno-palatine—in the anterior recess.

(1) The varying relations of the pituitary fossa to the sphenoidal sinus may be shown by diagram. The bulge is absent in the pre-sphenoidal type, slight in the intermediate form, and well marked in a fair proportion of the post-sphenoidal sinuses. When a trans-sphenoidal crest is present it may mask the pituitary bulge, but at the same time indicate accurately the antero-inferior part of the fossa. The pituitary bulge is frequently not so marked as the carotid bulge with which it is continuous, and it is sometimes a little difficult to say from an internal inspection of the sinus where one ends and the other begins.

(2) The most constant part of the carotid bulge is that corresponding to the bend under the anterior clinoid process. This frequently causes a prominence even in sinuses of the pre-sphenoidal type. In sinuses of the post-sphenoidal type the artery may cause a sinuous convexity along the lateral aspect of the wall of the cavity. The carotid bulge is frequently partly hidden by the bony buttresses which support it. When there is a well-developed lateral recess the artery lies wholly on the roof of the sinus.

(3) The optic nerve frequently causes a bulge into the antero-superior part of the sinus, and, according to the degree of its projection into the cavity, there may be developed supra- or infra-optic recesses.

(4) When the lateral recess extends sufficiently far out, there may be slight or even well-marked bulging caused by the maxillary division of the fifth cranial nerve. When the sinus extends beyond the foramen rotundum the nerve will sometimes bulge into the roof of the cavity. In 50 cases of this series there was a maxillary bulge.

(5) The Vidian nerve may also cause a bulge, or, strictly speaking, a ridge, on the floor of the lateral recess. In two or three specimens part of this ridge has been wanting in the dried bone, and clearly the nerve must have been separated from the interior of the cavity by a thin layer of soft tissues. The Vidian ridge or bulge was seen in 25 cases in this series.

(6) When the anterior recess is well marked, a vertical bony pillar will be seen leading down from the spheno-palatine foramen and marking the lateral boundary between the main cavity and the anterior recess. This bulge could appropriately be called the spheno-palatine pillar. It is caused by the vessels and nerves descending from the spheno-maxillary fossa.

A NOTE ON THE DUCTUS CAROTICUS AND DUCTUS ARTERIOSUS AND THEIR DISTRIBUTION IN THE REPTILIA.

By CHAS. H. O'DONOGHUE, D.Sc., F.Z.S., *Senior Assistant in the Zoological Department, University College London.*

OWING to the kindness of Professor A. Dendy, F.R.S., I have been able to examine the vascular system of the New Zealand Tuatera (*Sphenodon punctatus*), and I wish to express my thanks for the opportunity of so doing. When dealing with the main arterial roots in the course of this examination it soon became evident that a certain amount of confusion exists in literature concerning the nomenclature of portions of the embryonic arterial system usually fated to disappear but which may remain in a functional or vestigial condition in the adult. It seemed worth while calling attention to this matter in order that the muddle should not be perpetuated.

The foundation of our modern knowledge of the transformation of the arterial arches in the Amniota was laid by Rathke (35) in 1857 in his masterly paper on the aortic roots in Saurians. He pointed out that in the embryo five pairs of arterial arches were present on each side joining the ventral to the dorsal aortæ, Van Bemmelen (5) in 1886 described a transitory arch between the 4th and 5th in Rathke's series. This transitory arch was recorded in man, the rabbit, and the sheep by Zimmerman (40 and 41), and later by Tandler (38) in rat and man,[1] and Lehman (28 and 29) in rabbit and pig. Lewis (30) threw some doubt on the presence of this vessel, and suggested that comparative anatomical considerations had led observers to describe as a vessel what was in reality an indefinite meshwork of small vessels. However, more recent workers have reported the presence of this vessel in other mammals, viz.: in the mole, Soulié and Bonne (37); in the cat, Coulter (19); and in the pig, Reinke (36). There can be little doubt, then, that in the embryos of Amniotes in general six arterial arches make their appearance; the fifth, counting from before backwards, was overlooked by Rathke, is transitory and not so well developed as the remainder, and often apparently runs into the sixth on

[1] A good review of these changes as they apply to the condition in man will be found in Evans's article (21) in Keibel and Mall's *Manual*.

the dorsal side instead of into the dorsal aorta. In the transformation to the adult condition, as is well known, the first two and the fifth arches disappear, leaving the third, fourth, and part of the sixth as the carotid, systemic, and pulmonary arches respectively. From the third arch the continuation forward of the dorsal aorta constitutes the internal carotid, and the prolongation of the ventral aorta the external carotid. It is probable that the dorsal portions of the first and second arches remain to form the roots of the supra- and infra-orbital arteries respectively. The fourth arch forms the systemic stem, and in reptiles persists on both sides, in birds on the right only, and in mammals on the left only. A branch from the sixth arch on each side constitutes the pulmonary trunk. Certain other parts of the embryonic vessels may remain in a more or less well-developed condition in the adult, and it is respecting the nomenclature of these that the confusion exists.

I. The Ductus Caroticus.

This is a connection in the adult joining the carotid and systemic arches, and usually situated somewhat laterally where both these arteries are

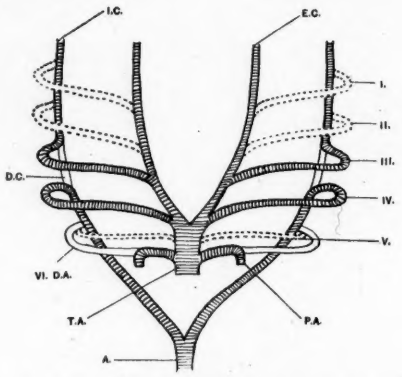

Fig. 1.—Diagram of the arterial arches of an Amniote embryo, to indicate vessels remaining in adult reptiles.

Dotted lines indicate vessels that disappear. Plain lines indicate vessels that may persist as ductus or ligamenta. Shaded portions indicate vessels that persist in the adult. I.–VI., the six embryonic arches; III., the carotid; IV., the systemic; A., dorsal aorta; D.A., ductus arteriosus (Botalli); D.C., ductus caroticus; E.C., continuation of the ventral aorta to form the external carotid artery; I.C., continuation of the dorsal aorta to form the internal carotid artery; P.A., pulmonary artery; T.A., truncus arteriosus.

bending round the œsophagus. It is actually a persistent portion of the embryonic dorsal aorta, and may be represented merely by a thin strand of

tissue with no lumen, as for example in *Rana*, in which condition it may perhaps be termed more strictly a ligamentum caroticum, or as a widely open vessel, a ductus, as in *Sphenodon*. In this form, too, it gives off a fair-sized artery, the arteria muscularis cervicis.

II. The Ductus Arteriosus or Ductus Botalli.

This structure, usually closer to the heart than the former, represents the continuation of the pulmonary arch from the point of origin of the pulmonary artery to the dorsal aorta. It is not part of the embryonic dorsal aorta like the foregoing, but, like it, may be present in the adult as a solid strand or as an open vessel. Van Bemmelen (5) found it in the larger of the two examples of *Sphenodon* he examined, and in the same species I have found it to be present generally in the form of a small but definite artery joining the two trunks. It is subject to more variation among the Reptilia than the ductus caroticus. Sometimes it remains open, *i.e.* a ductus, but is never so large as the former structure; it may be simply a strand of tissue or ligamentum: or yet again it may be partly open and partly solid, as is frequently the case in the Ophidia. There is also a certain amount of evidence to show that it may gradually close up during the life of the individual after it has reached the adult condition.

In this country the confusion has arisen since either of these vessels indiscriminately has been termed the ductus Botalli, whereas the two structures are distinct and of different morphological value. It has become almost general to describe the ductus caroticus as the ductus Botalli. Bourne (13, vol. ii. p. 275) states that the connexion between the first and second aortic arches in *Rana* persists in the adult as the ductus Botalli; Thomson (39, p. 626) refers to the ductus Botallii (*sic*) in *Lacerta* as joining carotid and systemic arches; and Marshall (32, p. 30) gives the same account for *Rana*. Beddard, whose papers have added so greatly to our knowledge of the vascular system in the Reptilia, also adopts the same terminology. In a diagram of the principal arteries of *Sphenodon* (4, p. 463) he figures this vessel quite accurately, but terms it the ductus Botalli; again in *Tupinambis* and *Iguana* (2, p. 466) he portrays the same artery; and lastly (3, p. 609), he states that no ductus Botalli joins the systemic and carotid arch in *Heloderma*, *Varanus*, and *Amphisbæna*. He uses the term again in the same sense (1, p. 331) in reference to a paper of Brandt's. In all these cases it is the ductus caroticus that is being dealt with.[1]

[1] The same misuse of the term ductus Botalli, only in the case of birds, is met with in a note by Finn, "On a Functional Ductus Botalli in *Nycticorax violaceus* and *Dafila spinicauda*," *Proc. Zool. Soc.*, Feb. 1891.

Parker and Haswell (34, vol. ii. p. 306) describe a true ductus Botalli in the Urodele *Salamandra*, but a few pages further on (p. 326) apply the same term in *Lacerta* to the connection between carotid and systemic arches. All authors apply the term correctly in the mammals, in which, of course, a ductus caroticus is not present.

There is no doubt whatever as to what structure Botallus himself meant, for he was dealing with a mammal, man, in which there is no ductus caroticus. In his *Opera Omnia* (11) the vessel is dealt with in Observatio III.: "Vena arteriarum nutrix a nulla antea notata" (p. 66). It is figured on p. 68 in a not very clear drawing, but described there under "Figuræ tertiæ Explicatio" as 'F.F. Canalis a pulmonali arteria tendens in aortam." This is the true ductus Botalli, or, as it has been subsequently named, the ductus arteriosus. The other vessel is the ductus caroticus, as it was first termed by Brandt (14).

Both these vessels are present in the embryo, and, as Boas (7) has recorded, present in the young frog and in the salamander at the time of metamorphosis. The same author describes them in the adult *Menopoma* and *Amphiuma* (8), and figures them also in a scheme of the vessels in the adult Triton (9). Fritsch (22) gives a diagram of *Cryptobranchus* in which not only are both these connections present, but also the fifth arch between the systemic and the pulmonary. From these facts we may justifiably conclude that the presence of both structures indicates a lack of specialisation in these regions, and a consequent retention of a fairly primitive condition.

It does not appear out of place here to glance briefly at the distribution of these two vessels or their vestiges in the Reptilia, and for convenience the orders of the class will be the same as those given by Boulenger (12).

Rhynchocephalia.

The sole living representative of this order is *Sphenodon punctatus*. In this form the ductus caroticus is well developed on both sides, as recorded also by van Bemmelen (5) and Beddard (4), and has a diameter as large as that of the external carotid. From it is given off a moderate-sized vessel, the arteria muscularis cervicis. The ductus arteriosus is also present, as pointed out above, as a distinct though small artery on each side. Thus the vessels in this form retain on both sides the connecting trunks found in the embryo. It might be suggested, of course, that this arrangement has been reacquired in a secondary way by the retention of larval structures that had disappeared phylogenetically; but taking into consideration various other points in the vascular system, it is much

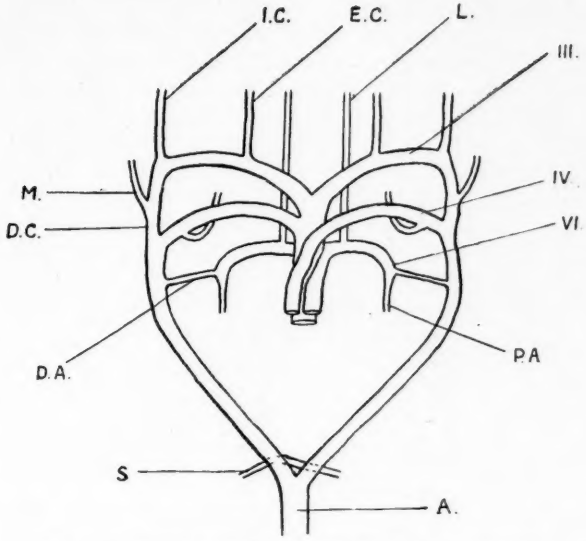

FIG. 2.—Diagram of the arterial arches in *Sphenodon punctatus*.

L., laryngeal artery; M., arteria muscularis cervicis; S., subclavian artery. Other letters as in fig. 1.

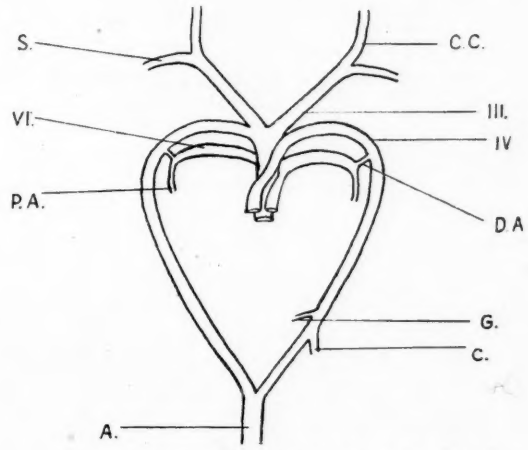

FIG. 3.—Diagram of the arterial arches in *Testudo græca*.

C.C., common carotid artery; G., gastric artery; C., cœliaco-mesenteric artery. Other letters as before.

safer to regard the arrangement met with in *Sphenodon* as a primitive one. In this respect, as far as is known, *Sphenodon* is more primitive than any other living reptile.

Chelonia.

In his exact account of the anatomy of the tortoise, *Testudo europœa*, Bojanus (10) figures and describes a ductus arteriosus—ductus arteriosus Botalli, as he terms it—on both sides. He does not mention the presence of a ductus caroticus, and in such a careful, detailed piece of work as this is, it does not seem probable that he overlooked it. Gegenbaur (23, vol. ii. p. 385) records the persistence of a small open ductus Botalli on both sides in Chelydra, but makes no mention of the ductus caroticus. Fritsch (22, p. 701) gives a diagram of the heart and vessels in one of the "Schildkröten" (*Chelydra serpentina*?), in which a ductus Botalli is shown on both sides, but no indication of the other connection. Mackay (31) is still more definite, and asserts that in a number of Chelonia (species not given) that he has dissected he has not found a ductus caroticus. Brenner (17) states that in *Testudo græca* the pulmonary artery undergoes a sudden reduction in diameter at the point where the ductus Botalli should be given off, but was unable to find a trace of that structure on either side. This is an interesting point, as a similar reduction occurs in many forms, particularly in the Ophidia. Hochstetter (25), however, in the same form figures (pl. xxiv. fig. 9) a ligamentum on both sides, states that he has found it in various species of the order, and provides the following interesting footnote: "Auch van Bemmelen [6] spricht von einem Erhaltenbleiben des Ductus Botalli bei Hatteria und einer Reihe von ihm untersuchter Schildkröten. Eine briefliche Anfrage an diesen Autor ergab jedoch, dass er mit seiner Angabe nur hervorheben wollte das Reste der Ductus Botalli bei diesen Formen regelmässig erhalten bleiben dass er diese Reste aber auf ihre Wegsamkeit hin nicht untersucht habe." No mention is made of either vessel in Jacquart's memoir (26) on the heart of *Chelone midas*, but it is not improbable, in the face of the above evidence, that they were overlooked, although he has a note on the ductus Botalli in the human heart in the same paper.

From the foregoing, then, it would appear as if in the Chelonia the ductus caroticus is normally absent, while the ductus arteriosus is represented on both sides.

Crocodilia.

Rathke (*l.c.*) did not find a ductus caroticus in the following forms:—*Alligator lucius, A. sclerops, A. palpebrosus, A. trigonatus, A. cynocephalus,*

A. punctulatus, Crocodilus vulgaris, C. piboreatus, C. rhombifer, C. acutus, Gavialis gangeticus and *G. Schlegelli.* This vessel has been found in certain forms, however; *e.g.* it is recorded as present but almost closed on both sides in *Alligator mississippensis* by Brandt (16), and in spite of the poor description and very schematic drawing it seems as if he was probably right. Greil (24) also records a left ductus in the crocodile. Hochstetter (25) has recorded ligamenta in one specimen of *A. lucius* 1·5 metres long, but apparently did not find it in three others; and Mackay (31) in a small *Crocodilus niloticus* 29 inches long found a ductus on both sides. It is by no means certain, however, that such cases are not either young animals or exceptional examples, and probably the ductus caroticus is not usually present in the full-grown members of this order.

Not much is known of the ductus arteriosus, although Hochstetter (*l.c.*) has found ligamenta in four separate old specimens of *A. lucius,* while Davenport (20) in two examples, whose age is not given, found open ductus.

Further work is needed on the Crocodilia before it is possible to give a generalised statement of the condition of these vessels; but, as will be seen, both structures may be represented, but the ductus caroticus is probably absent as a rule.

Lacertilia.

Much more is known about the vessels in the Lacertilia, owing mainly to the pioneer work of Rathke (*l.c.*). Under the name of the "Absteigender Schenkel des Carotidenbogen" this author has recorded the presence of a ductus or ligamentum caroticum in the following species:—*Acontias meleagris, Anguis fragilis, Chamæasaura anguina, Lacerta ocellata, Ameiva vulgaris, Draco viridis, Lacerta agilis, Lophyrus giganteus, Agama mutabilis, Phrynosoma Harlœnii, Uromastix spinipes, Cuprepis Merremii, Gongylus ocellatus, Cyclodus nigroluteus, Platydactylus ægypticus, Ophisaurus ventralis, Pseudopus Pallasii, Iguana tuberculata, Lyriocephalus margaritaceus, Agama colonorum, Grammatophora barbata, Zonunus cordylus, Platydactylus guttatus, Istiurus amboinensis, Tejus Teguixin,* and *Basiliscus mitratus.* It is found in all stages of development, and in the above list the species are placed approximately in order, the best-developed first, and in the case of the last three it becomes practically obliterated, being represented merely as a strand. Indeed, in *Tejus Teguixin* Brücke (18) has reported a case in which they are entirely absent.

No trace of it is to be found in *Chamæleo vulgaris, C. pumilus, C. verrucosus,* and *C. tigris,* but it is present in *C. planiceps* as a tiny ligamen-

tum visible with the aid of a hand lens. It appears to be lacking in *Varanus ornatus, V. bivitattus,* and *V. niloticus,* and also in *Amphisbæna alba, A. fuliginosa, A vermicularis,* and *Lepidosternon microcephalum.*

Kükenthal figures ductus carotici in *Lacerta agilis* (27), and Brandt (15) records them in *L. crocea* (*Zootoca vivipara*).

Beddard, as pointed out above, has found ductus in *Tupinambis nigropunctatus* and *Iguana tuberculata,* while he reports them as missing in several species of *Varanus* and *Amphisbæna* and in *Heloderma suspectum.*

It will be seen that in general there is a fair correspondence between the position of the heart and the persistence of the ductus caroticus. In

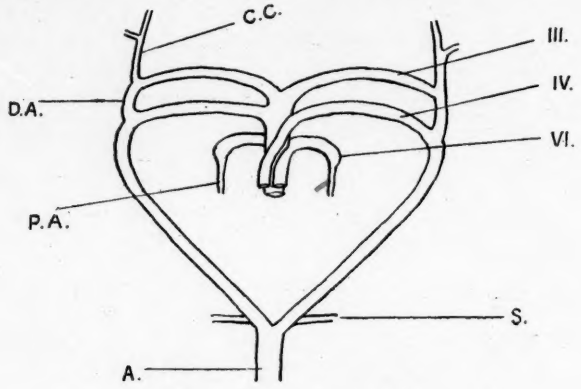

FIG. 4.—Diagram of the arterial arches in *Lacerta viridis.*

Lettering as before.[1]

the forms in which the heart is far removed from the head the ductus disappears, and in these forms too a carotis primaria is often developed, and *vice versa.* One striking exception is *H. suspectum,* where, as Beddard has pointed out, there seems to be no reason why a ductus should not be present; it is nevertheless absent.

Hochstetter (*l.c.*) states that he has found ligamenta Botalli in all the large Lacertilia in which he has sought it, viz.: *Varanus griseus, V. rarius, V. niloticus, Hydrosaurus salvator, Uromastix spinipes, U. Hardwickii, Pseudopus Rallasii,* and others. Sometimes it is represented only by a small stump on each side in *H. salvator,* and on the right side only in *Platydactylus annularis.* Brenner (17) points out that in *Lacerta* he

[1] It will be noticed that the term "common carotid artery" (C.C.) is applied in this form to a vessel that appears to be the morphological equivalent of the internal carotid artery.

has found no ligamentum, but a reduction in the diameter of the pulmonary artery marking its position. The same condition apparently exists in *L. agilis* and *L. viridis*.

In the Lacertilia, then, a ductus caroticus is present in a number of cases, though only in a few is it as well developed as in *Sphenodon*; in most it shows a certain amount of reduction, and in others is absent altogether. The ductus arteriosus when present is in the form of a ligamentum or reduced to a small stump, or when absent its former position may be marked by a reduction in the calibre of the pulmonary artery.

Ophidia.

The last and in some ways the most specialised order of reptiles is the Ophidia. According to Brandt (14) the grass snake, *Tropidonotus natrix*,

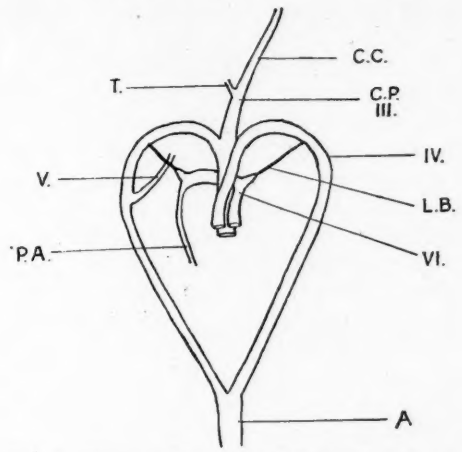

Fig. 5.—Diagram of the arterial arches in *Vipera berus*.

C.P., carotis primaria; L.B., ligamentum arteriosus (Botalli); T., thyroid artery; V., vertebral artery. Other letters as before.

possesses a solid strand of tissue joining the transverse part of the left aortic arch to the carotis primaria, and so representing a ligamentum caroticum. He states that it is a vestigial structure in some ways resembling the ductus Botalli, and homologises it with the "Absteigender Schenkel des Carotidenbogens" of Rathke, proposing for it the name of "ductus caroticus." I have had occasion to point out previously (33) the doubtful nature of this vessel. No connexion exists in this position in the

course of embryonic development. From its very nature as a remnant of the dorsal aorta of the embryo this vessel must be considerably dorsal to the external carotid, and, indeed, in a line with the internal carotid, whereas the strand described by Brandt was not only ventral, but considerably posterior to the external carotid. Moreover, I was unable to find any trace of it in the snakes then examined, and have also been unsuccessful in a number of specimens since dissected. Brandt (*l.c.*) also describes a strand in a similar extraordinary position in *Pelias berus*, and adds that he found it hollow in three out of twenty full-grown examples, and also in some young ones. Hochstetter, in mentioning this, points out that he dissected very carefully three injected examples of *P. berus* and numerous examples of *T. natrix*, and other snakes, paying particular attention to this point, but found no trace of such a vessel. In the two adult specimens of *Pelias* (*Vipera*) *berus* that I examined to check the matter the result was the same as Hochstetter's—no ductus or ligamentum was found.

Ductus Botalli are frequently represented on both sides in snakes, although, as is well known, the right lung and pulmonary artery are generally suppressed, with some exceptions, *e.g.* the Uropeltidæ, where it is the left lung and artery. Not only is a ligamentum present, but the most posterior portion often remains open as a small conical sac. In those forms having only one lung and yet having two ductus, the pulmonary arch on the side on which the lung has gone persists up to a point where it is joined by a ligamentum. Frequently, also, a reduction in the diameter of the pulmonary artery occurs just posterior to this point; this has been noticed by Fritsch (22) in *Boa* and *Python*, and Hochstetter (25) in *Boa constrictor*. In the same paper the latter author records the presence of two ductus in *Tropidonatus natrix*, *T. tesselatus*, *Coluber æsculapii*, *Coronella lævis*, *Vipera berus*, *Dryophis mycterigans*, and *Cerastes vipera*. I have also found them in *V. berus*, while I find myself in agreement with Brenner (17) in being unable to find a right ligamentum in *T. natrix* in any of the many examples I have dissected. Certain variations in these structures may occur, for Hochstetter (*l.c.*) describes a *B. constrictor* $2\frac{3}{4}$ metres long in which the ductus remained open on the left but was absent on the right, and a full-grown *C. lævis* in which the right ductus remained open.

As far as can be ascertained, the ductus caroticus does not persist in any adult Ophidian, but the ductus arteriosus is represented by a ligamentum the posterior part of which may remain open as a short conical sac. Generally, two ligamenta are present one on each side, even though the lung and its artery may be suppressed on one side.

SUMMARY.

Three of the six embryonic arches persist in the adult reptile, and of their connecting vessels both ductus carotici and ductus arteriosi may persist or be represented by ligamenta.

In *Sphenodon* both ductus are to be found on each side.

In Chelonia the ductus carotici are usually absent, while the ductus Botalli remain.

In Crocodilia the ductus carotici are probably not usually present, and the ductus Botalli may probably remain.

In Lacertilia the ductus carotici are present very generally, although in a number of species they are reduced or absent, and the ductus Botalli are always reduced and very often absent.

In Ophidia the ductus carotici are normally absent, but the ductus Botalli persist, and often on both sides, in spite of the suppression of one lung and pulmonary artery.

There seems to be little doubt that the main factor affecting the persistence or loss of these structures is the change undergone in the relative positions of the heart and arterial arches in the course of development and subsequent growth. Thus where little relative change takes place, as in *Sphenodon*, all connections are retained. In certain lizards that become relatively broad across the anterior thoracic region the ductus Botalli disappear, and in yet others, like the Varanidæ, where the development of a long neck is accompanied by the separation of the carotid arch from the remaining arches, the ductus carotici also go to the ground. This latter point is well illustrated in the Ophidia; where the carotid arch in the adult is widely removed from the others, the ductus carotici disappear. In the same group, also, owing to the marked lateral compression of the body, the systemic arch is kept in close proximity to the pulmonary, and as a result the ductus arteriosi are practically always represented.

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THE HUMAN PISIFORM.

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The few remarks I have to make on the human pisiform are intended as a preliminary to a communication on the condition in certain lower animals. The bone has suffered from the descriptive standpoint, being very small and irregular, and under suspicion of being a sesamoid. The descriptions even in the larger text-books are so lacking in detail, and apparently in accuracy also, that they hardly form a safe guide even to the side to which a given bone belongs; in about 50 per cent. of prepared skeletons the bone is incorrectly placed. I have examined a number of dry specimens, and have also dissected several fresh ones, and have endeavoured to arrive at its more prominent features, and the relation they bear to the soft parts.

The dorsal aspect of the bone requires no special description. It shows an oval facet, generally slightly concave, for articulation with the cuneiform. The long axis of the facet is directed distally and radially.

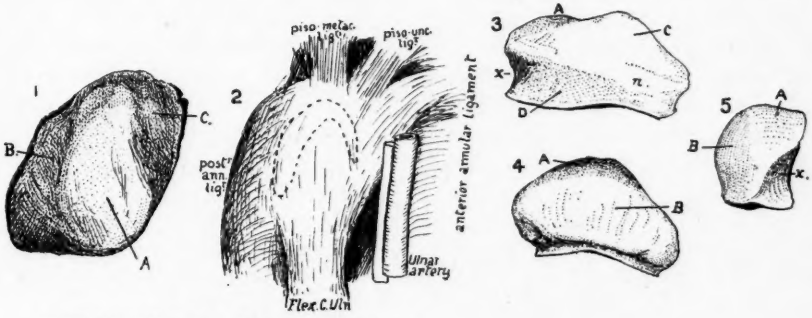
No. 1 in the figure represents a pisiform from the anterior aspect. Three surfaces are visible—an anterior, A; an internal or ulnar, B; and an antero-external, C. The surface A constitutes the main attachment of the tendon of flexor carpi ulnaris, as seen in the next figure. Many of its fibres, however, pass beyond to the surface C, to be attached there in a manner to be described presently.

The ulnar surface, B, receives, over a considerable area, fibres of the posterior annular ligament, and, at its distal end, of the piso-metacarpal ligament. Beyond the attachment of these fibres this surface gives direct origin to abductor minimi digiti, the muscle elsewhere arising from the ligaments only. This origin is shown as a dotted line in the figure.

No. 3 shows the bone from what is generally described as the radial aspect. It should be borne in mind, however, that, owing to the longitudinal axis of the bone having a distinctly oblique direction, this aspect is really proximo-radial. An oblique line can be seen clearly, running distally and dorsalwards on this aspect. The line varies from a roughened linear area to a prominent ridge. Its obliquity also varies considerably. It separates two surfaces, the anterior of which is the antero-external surface, C, already mentioned. The more dorsal of the two, D, becomes concave when traced proximally, until it forms a well-marked hollow, x, at the proximal end of

the bone. In the fresh specimen the distal part of the oblique line is seen to correspond to the attachment of the anterior annular ligament, which presents in this situation a free edge looking radially (see figure). The proximal part of the oblique line corresponds to the radial edge of the flexor carpi ulnaris tendon, the fibres of which have the appearance of being continued, along this line, into the free edge of the ligament. Actually, the bulk of the fibres are interrupted on the bone, but a few can generally be traced through.

Both the tendon and the ligament have other fibres spreading on to the surface C, forming a continuous attachment on this surface, but not presenting many continuous fibres. The abductor minimi digiti will



1. Right pisiform from the palmar aspect.
   A, anterior surface; B, ulnar or internal surface; C, antero-external surface.
2. Same, with soft parts in position.
   Dotted line represents attachment of abd. min. dig.
3. Radial aspect, showing oblique line separating surface C, placed antero-distal to it, from D, lying postero-proximal.
   x, hollow at proximal end; n, point where ulnar nerve comes first into close relation.
4. Ulnar aspect.
5. Proximal aspect.

generally extend its attachment on to the portion of the surface C which adjoins the surface A: the origin in such case being from fibres of the anterior annular ligament.

The more proximal surface, D, is in relation with the ulnar aspect of the common flexor sheath, except at the proximal end, where the well-marked hollow, x, here presented, lies under cover of the flexor carpi ulnaris tendon, and is occupied by a mass of areolar tissue connecting the common flexor sheath with the fascia on the dorsum of the wrist.

Of the two extremities of the bone, the proximal exhibits the hollow, x, mentioned above. The curved edge bounding this, and formed by the

proximal limits of the surfaces B and A, gives this end of the bone a characteristic appearance.

The distal extremity projects beyond the articular surface, and has a tubercle, often prominent, for the attachment of the piso-uncinate ligament.

These markings that I have described can be identified in all specimens, however apparently dissimilar. The ulnar nerve, if it comes into contact at all, is confined to the distal portion, where it lies palmar to the ridge for the attachment of the annular ligament. Moreover, even in adduction the nerve does not have a close relation with the groove which it has been generally credited with forming.

The other markings on the bone are caused secondarily as the result of the bone coming into relation with the deep aspect of the covering structures. The early position of the developing pisiform can be seen in reconstructions of the successive stages. In this lies the probable explanation of the varying appearances presented by the bone. These, however, can be more conveniently dealt with subsequently in considering the bone from the comparative standpoint.

OBSERVATIONS ON METOPISM.

By Professor THOMAS H. BRYCE, University of Glasgow, and MATTHEW YOUNG, M.D., Statistical Department, National Research Laboratory.

THE excellent summary given by Le Double[1] of the statistics of metopism shows that the condition occurs in from 9 per cent. to 10 per cent. of all European crania irrespective of race, of skull form, or of mental condition. Metopism is certainly more frequent in the white races, rarer in the lower races of mankind. It has not so far been observed in the anthropoid apes. More than forty years ago Welcker[2] furnished statistics which seemed to show that metopism occurred more frequently in brachycephalic than in dolichocephalic races, and the generalisation found some support from the observations of Papillaut.[2] Parsons[3] found a metopic suture persistent in the adult in 52 out of 590 specimens (*i.e.* 9 per cent. approx.) in the Hythe series of skulls, which are remarkable for their shortness, being practically equal to the South German in that measurement. He states that the number of metopic skulls occurring in the two sexes shows no appreciable difference, although, according to the figures supplied, there would appear to be some relationship between the frequency of the anomaly and age incidence. Under the age of twenty years the frequency was 20·8 per cent.; in the specimens between twenty and forty it was 9·8 per cent.; and in those over forty, 6·4 per cent. In Macdonnell's Whitechapel English series,[4] dolichocephalic in form, the frequency of the anomaly was 8·2 per cent. Turner in his *Challenger Report* (part xxiv., 1884) says of his 143 crania of aboriginal races from South Africa, South America, Australia, and the Pacific Islands that "the absence of the metopic condition was remarked in the aboriginal series," though he had seen it in the skulls of a Veddah and of an Andaman Islander. Flower observed metopism in six Andamanese crania. Statistics furnished by Le Double's article serve also to prove the greater rarity of the condition in the lower races of mankind.

In the long series of West Scottish skulls preserved in the Anatomy Department of the University of Glasgow, and described recently in a

[1] *Variations des os du crane de l'homme, etc.*, Paris, Vigot Frères, 1903.
[2] For references see Le Double.
[3] *Journ. Roy. Anthropol. Institute*, vol. xxxviii., 1908.
[4] *Biometrika*, vol. iii. p. 1412.

memoir Dr Young published in the *Transactions of the Royal Society of Edinburgh*[1], metopism occurs in 9·5 per cent. of the crania. The series is remarkably uniform in character, dolichocephalic in type, yet the percentage closely approximates to that in the Hythe series. From the series of 75 metopic skulls two groups were selected—consisting of 45 and 20 specimens respectively. The first group was attributed to the male sex, the second to the female, while the remaining specimens have been noted as doubtful. The determination of sex, difficult in all circumstances, is specially difficult and uncertain in the case of metopic skulls, because, as will afterwards appear, the frontal bone has in the majority of cases an upright character. We do not, therefore, lay emphasis on the sex characters, and in consequence the series are named A and B. A is preponderantly male, B preponderantly female.

Cranial Measurements.

Table I. shows the mean values for the measurements and indices of the cranial box of the metopic skulls in apposition to the mean values for the same measurements shown by the complete male non-metopic series of 405 skulls and the female series of 100.

The comparison is not without interest. Considering the absolute measurements first of all, we observe that, while the mean capacity of the metopic group A is slightly less than that, in the male non-metopic group, the opposite holds for the B series as compared with the female non-metopic.

The mean length in the A metopic group is about 3 mm. less than that shown in the male non-metopic group, while, though the mean length in series B is less than the normal female, there is less than one millimetre of difference in the values.

It is frequently stated that there is an increase in the mean maximum breadth of the metopic skulls in a series over the general value for maximum breadth. In the A series and the non-metopic male group the mean maximum breadths are practically identical, while in the B group the metopic mean is 1·29 mm. in excess of the female non-metopic mean. Parsons found the increase in the Hythe crania to equal about 1·3 mm.

In the Whitechapel series Macdonnell found the mean values identical in the metopic and non-metopic female crania, while in the male series the metopic group had a mean value 1 mm. in excess of that in the non-metopic group. These data go to show that if there is any increase in maximum breadth in metopic skulls over the normal members of a series it is very slight in degree.

[1] Vol. li. part ii. (No. 9).

TABLE I.

Character	Male. Non-metopic (405).	Series A. Metopic (45).	Female. Non-metopic (100).	Series B. Metopic (20).
(C) Capacity	1459·43±4·11	1444·32	1314·5 ±6·30	1354·5
(L) Length	187·52±·20	184·71	177·97±·20	177·15
(B) Breadth (maximum)	139·56±·16	139·46	135·16±·29	136·45
(B′) Breadth (minimum frontal)	96·42±·15	99·82	92·66±·25	96·8
(H) Height	132·72±·17	129·75	125·01±·31	126·75
(LB) Basi-nasal length	100·37±·13	98·2	93·82±·20	93·90
(U_2) Horizontal circumference (Turner)	526·60±·47	523·84	503·61±·71	505·9
(S) Sagittal arc	378·60±·43	372·02	363·15±·68	364·9
(Q) Transverse arc	311·10±·36	309·8	299·21±·60	302·35
(J) Zygomatic breadth	127·16±·18	125·5	118·16±·26	119·2
100 B/L	74·36±·08	75·53	76·03±·19	77·06
100 H/L	70·81±·09	70·28	70·31±·20	71·79
100 H/B	95·14±·14	93·04	92·53±·29	92·88
Frontal arc	131·73	128·26	126·96	126·5
Parietal arc	127·00	124·68	121·4	121·05
Occipital arc	119·88	119·06	114·76	117·35
Interstephanic diameter	117·93	120·42	114·91	119·85
Asterionic diameter	109·68	108·57	105·44	106·3
Transverse base	115·13	114·02	108·89	109·4

A glance at the table will show that the mean value of the other measurements is slightly greater in the male non-metopic group than in the metopic series A, while the reverse holds for the B series as compared with the female non-metopic group.

Two exceptions to the general rule exist in the greater frontal breadth in both series. This holds for both the frontal and interstephanic diameters.

It has long been known that the minimum frontal breadth is greater in metopic skulls. Cleland refers to the point in his memoir[1] on the skull. The late closure of the suture apparently permits the forehead to broaden. Parsons states the increase to be 6 mm. over the normal in the Hythe series, while in Macdonnell's series the excess was 2·3 mm. in value.

In the present series the mean increase, over the non-metopic groups, in minimum frontal breadth is 3·5 mm. in series A and 4 mm. in series B; the mean increase of the interstephanic diameter is 2·5 mm. for series A, 5 mm. for series B.

The cephalic index is higher by one point in the metopic group than

[1] *Phil. Trans. Roy. Soc. London*, vol. clx., 1870.

in the normal skull, the difference being due, as the mean breadths are practically equal, to the diminution in mean glabello-occipital length.

This greater metopic cephalic index is also shown by the Whitechapel English series, the Moorfields English series, and the Hythe English series of crania, and is evidence of the fact that within the same series the metopic representatives are on the average more brachycephalic than the normal skulls.

The vertical index is little altered, as height and length are apparently proportionately diminished, while the height-breadth index is slightly reduced owing to the fact that the height is diminished while the breadth remains the same. A reference to the absolute measurements will in the same way explain the differences in the indices in the B series as compared with the non-metopic female group.

While there are notable differences in the relations of the values in the two types of skull to which reference will be made presently, the measurements for minimum frontal breadth and interstephanic breadth stand out from the others as showing a very appreciable change in value in the same direction in passing from the metopic to the non-metopic skull.

An analysis of the values in the A series might incline one at first sight to suggest that, as length and height are reduced in the metopic form while the capacity is not correspondingly diminished, the greater frontal breadth, and consequently the persistence of the suture, might have been necessitated by what may be termed a "compensatory increase" in the frontal region. This has been suggested by various writers. The explanation is rejected by Le Double, and the B series does not tend to support it. The frontal breadth shows a greater divarication than in the A series in favour of the metopic form, while the other measurements remain very slightly in excess of those of the normal group of female skulls.

Here we have an increase in cranial capacity associated with an *absolute* not a *compensatory* expansion of the frontal region of the skull. Had the mean capacity in series B fallen, as in series A, below that of the group compared, there would have been the same diminution in length and height and related dimensions as in series A. The two series taken together rather point to metopism, when not due to pathological conditions, being a progressive manifestation. The fact that metopism is rare in the lower races of mankind lends support to this conclusion.

Correlation.

As the frontal breadth is the character found to exhibit a distinct difference in magnitude in the metopic and normal groups, with the excess

in favour of the metopic form, we have made the necessary calculations to determine the correlation existing between this and other measurements of the skulls in the series in order to compare the values found with those for the normal group, hoping that by this means some causal factor for the persistence of the suture would be revealed. The great uniformity of the West Scottish series favours such an inquiry. The coefficients calculated are shown in Table II.

TABLE II.—COEFFICIENTS OF CORRELATION IN MALE SEX.

Pair of characters.	Metopic group.	Non-metopic group.
B′ and L	·45 ± ·080	·37 ± ·029
B′ and B	·59 ± ·065	·39 ± ·029
B′ and H	·47 ± ·080	·28 ± ·031
B′ and C	·52 ± ·073	·42 ± ·027
B and L	·55	·454 ± ·026
L and H	·45	·356 ± ·029
B and H	·45	·264 ± ·031
B and C	·72	·73 ± ·017
L and C	·74	·69 ± ·017
H and C	·66	·56 ± ·024
C and U	·83	·78 ± ·013
C and Q	·76	·76 ± ·014
Frontal segment and total sagittal arc	·665	·73 ± ·017
Parietal segment and total arc	·58	·53 ± ·025
Occipital segment and total arc	·54	·77 ± ·013

B = Maximum breadth.
B′ = Minimum frontal breadth.
L = Maximum length.
H = Basibregmatic height.
C = Capacity.
U = Horizontal circumference.
Q = Transverse arc.

The coefficient of correlation between the minimum frontal breadth and the absolute measurements for length, breadth, and height respectively, is in both series—metopic and non-metopic—greater for breadth than for the other two, so that the minimum frontal breadth shows a greater tendency to increase where the maximum breadth increases than when length and height increase, although it also shows a well-marked and almost similar tendency to do so in the last two cases in the metopic group.

While the correlation between maximum breadth and capacity shows practically identical values in the two series, indicating that these characters have similar tendencies to vary in metopic and non-metopic forms, the correlation between minimum frontal breadth and capacity is definitely greater in the metopic than in the normal series, a fact which points to a closer relationship between these dimensions in the former than in the latter group.

An increase in capacity may be obtained by one or more of the dimensions becoming greater in value. In the normal series it was proved that all three chief diameters tend to increase proportionately as the brain-case expands. It would appear that in the metopic series increase in capacity is obtained more frequently, and to a greater extent, by increase of the minimum frontal diameter than in the normal series.

From the evidence here supplied it appears that within a uniform series an approximation to a certain capacity is attained by at least two methods—one in which development goes on in what we regard as the normal way with the closure of the metopic suture at an early stage and expansion more particularly in the hinder part of the vault; another in which there is greater growth in the frontal region, associated with the persistence of the suture for a longer period, or till a later age, than normally to permit of such an increase.

The Closure of the Sutures.

It is frequently stated that the metopic suture, having persisted till adult life, shows less tendency to fuse than the other sutures, and that it is the last to undergo synostosis. Parsons and Box found no evidence in favour of such a view in the skulls examined by them.

In the present series of 70 skulls three groups may be taken as follows:—

A group A of 29 skulls in which the basal suture has completely fused, and the 3rd molars have either erupted or appear in the cavities of their alveoli, or have failed to erupt. In these 29 skulls all the sutures are open.

Group B of 10 skulls, many edentulous, showing very advanced stages of suture obliteration.

Group C, a middle group of 39 skulls showing various degrees of synostosis, from the very commencement of the process to a fairly advanced stage in some cases.

Groups A and B cannot, obviously, throw any light on the condition of metopism, but it seemed possible that the details in the middle group might provide some further information. The results are shown in Table III.

A consideration of the table brings out the fact, already well known, that synostosis, so far as the outer aspect of the sutures is concerned, begins either in the inferior part of the coronal suture or in the sagittal suture in the region of the obelion.

In this series it is obvious that the closure of the sagittal suture precedes that of the coronal suture, and, what is more interesting, that in

TABLE III.

B = bregmatic part. V = vertex. O = obelion. L = lambda

B = bregmatic part. C = complex part. T = temporal part.

L = lambdoid part. M = middle part. A = asterionic part.

S = superior part. M = middle part. I = inferior part.

S = superior part. I = inferior part.

Series No.	S. sagittalis.				S. coronalis.			S. sphenofrontalis.	S. lambdoidea.			S. sphenoparietal.	S. mastoccipit.			S. sphenotemp.		
	B.	V.	O.	L.	B.	C.	T.		L.	M.	A.		S.	M.	I.	S.	I.	
A_2	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	
A_3	–	+	+	+	–	–	+	+ : –	+	–	–	–	–	–	–	–	–	Edentulous.
A_4	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
A_5	+	+	+	+	–	–	–	+ : –	+	×	–	–	–	+	+	–	–	Edentulous.
A_6	+	+	+	+	–	–	–	–	+	+	–	–	–	–	–	–	–	3rd molars in alveoli.
A_7	+	+	+	+	–	–	–	–	+	+	–	–	–	–	–	–	–	"crane en toit."
A_8	–	–	+	–	–	–	–	+ : –	–	–	–	–	–	–	–	–	–	
A_{10}	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
A_{11}	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
A_{12}	–	–	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	Edentulous.
A_{13}	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
A_{14}	–	×	+	×	–	–	–	–	–	–	–	–	–	–	–	–	–	
A_{15}	–	–	+	–	–	–	+	+ : ×	+	–	–	+ : –	–	–	–	–	–	3rd molars failed.
A_{16}	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Edentulous.
A_{18}	–	+	×	–	–	–	+	+	–	–	–	×	–	–	–	–	–	3rd molars in alveoli.
A_{20}	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Edentulous.
A_{22}	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	
A_{24}	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
A_{25}	–	×	+	+	–	–	–	–	+	×	–	–	–	–	–	–	–	Edentulous.
H_1	–	–	+	–	–	–	+	–	+	+	–	–	–	–	–	–	–	3rd molars unerupted.
H_2	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
H_4	–	+	+	+	–	–	×	–	–	–	–	–	–	–	–	–	–	
H_6	×	+	+	+	–	–	+	×	+	×	–	–	–	–	–	–	–	
H_8	–	+	+	–	–	–	+	+	–	–	–	–	–	–	–	–	–	
H_{11}	–	–	×	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
H_{13}	–	–	+	–	–	–	–	–	×	–	–	–	–	–	–	–	–	
H_{14}	–	–	–	–	–	–	+	–	+	–	–	–	–	–	–	–	–	
H_{15}	–	–	×	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
H_{21}	–	–	+	×	–	–	×	–	×	–	–	–	–	–	–	–	–	
B_3	–	×	+	×	–	–	+	–	+	×	–	–	–	+	+	–	–	Edentulous.
B_{10}	–	–	–	–	–	–	+	+ : –	–	–	–	–	–	–	–	–	–	
B_{12}	–	–	–	–	–	–	×	– : ×	–	–	–	–	–	–	–	–	–	
B_{14}	–	–	+	–	–	–	–	× : –	–	–	–	–	–	–	–	–	–	
B_{15}	–	+	+	+	–	–	×	–	+	+	–	–	–	–	–	–	–	
B_{16}	–	–	+	×	–	–	–	–	–	–	–	–	–	–	–	–	–	
B_{18}	–	–	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	
B_{19}	–	–	+	×	–	–	+	+	–	+	–	+	–	–	–	–	–	Edentulous.
B_{25}	–	–	+	×	–	–	–	–	–	–	–	–	–	–	–	–	–	
Y_1	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	

– = open ; + = closed ; × = closing.

In case of difference on two sides, facts represented thus, left right + : –

a number of cases there is considerable fusion both in the sagittal and lambdoid sutures without any signs of synostosis in either the coronal or spheno-frontal sutures. If Parsons and Box[1] are correct in fixing the inferior part of the coronal suture as the first situation to show signs of closure in the majority of cases, then this metopic series is exceptional and agrees with Frederic's[2] series of middle-European crania, broad in type. The condition of metopism is of course established at a time when the question of suture closure does not arise, but the facts may have some significance, viz.—first, that in this metopic series all the frontal sutures show a tendency to remain open, while the sutures in the region of the lambda reveal a tendency to close earlier than the anterior sutures; and, second, that in this respect the skulls agree with a series of skulls brachycephalic in form.

A feature of this series which seems more than a mere coincidence is the frequency with which the upper end of the interfrontal suture becomes confluent with the coronal to the right side of the anterior extremity of the sagittal suture. Out of 72 skulls the confluence was to the right of the sagittal suture in 53 per cent., while in 36 per cent. the two sutures enter the coronal exactly opposite one another. In only 11 per cent. did the confluence lie to the left of the sagittal suture. Perhaps this is to be regarded as further evidence of the asymmetry due to greater development of the left side of the brain in association with the prevalence of right- over left-handedness.

Stieda[3] suggested that the change in the position of the confluence is due to variation in the mode in which a variably developed fontanelle bone present at an early stage becomes fused with the adjacent frontal. One juvenile metopic skull in the series proves the possibility of this explanation, but otherwise we can neither deny nor affirm the theory.

Morphological Features.

It is known, as stated above, that the metopic suture persists with greater frequency in the white races of mankind. It has also been proved afresh that although metopism occurs with equal frequency in both dolichocephalic and brachycephalic races, the individual specimens in which it is present are more brachycephalic on the average than the others in the series. By comparison of the West Scottish with the Australian and Tasmanian skull it has already been proved that the greater capacity is due to a certain increase in breadth, a slight increase in length, and a marked increase of depth behind. Both by correlation and morphological

[1] *Jour. Roy. Anthropol. Institute*, vol. xxxv., 1912.
[2] *Zeitschr. f. Morphol. u. Anthropol.*, Bd. ix., 1906.
[3] *Anat. Anzeiger*, Bd. xvi, 1897, p. 226.

analysis the proof was furnished that in the series studied the occipital region of the skull was chiefly responsible for the increase in calvarial height, and therefore an important factor in the cranial expansion. In the present paper it has been proved both by measurement and correlation that there is an absolute lateral expansion of the frontal region in the metopic skull. We therefore proceeded to determine by more detailed analysis what other morphological changes were associated with this expansion, and a series of sagittal outlines of 50 metopic skulls comprising series A and a few others was prepared. The necessary measurements were made and indices calculated from those in order to obtain the data for comparison with those already obtained in a normal series of skulls of the same type. Another motive here entered, viz. that, apart from establishing certain facts for the metopic series, there was the possibility that, by determining any distinguishing morphological features in the metopic as compared with the non-metopic group, some information might be obtained which would throw light on the wider question of the meaning of differences in skull forms.

Before proceeding to an analysis of the measurements and indices, there are certain general morphological features which may be described.

An examination of the individual members of the series conveys the impression that the frontal bone, in addition to being wider, is more vertical and more curved. This is not always the case in the older specimens, but in the younger skulls it is a very marked feature, and the infantile character of the frontal is retained.

In many specimens there is a more or less well-marked post-coronal constriction. Out of 76 skulls examined this was well marked in 31 specimens, slightly marked in another 33, and totally absent in only 12 cases. This character, however, is not peculiar to the metopic skulls of the West Scottish series, although it seems to occur more frequently in them. In a very considerable number of non-metopic skulls a dip occurs in the vault behind the bregma associated with a flattening on each side behind the coronal suture. In certain cases this is so marked that the appearance is as if the skull had been compressed by a tight band carried across the vault. It is further interesting to note that the lateral flattening over the fore and upper part of the parietal bone is frequently unilateral, and, when on one side only, is almost invariably on the right side. The nature and significance of this feature—post-coronal flattening, depression, or constriction, as it may be termed according to its degree—cannot be discussed here. It demands further analysis than we have yet been able to give it. It suffices to record the frequency of its occurrence in the metopic skulls of the series.

In two of the 12 metopic skulls in which there was no post-coronal

depression there was a frontal crest, in one of them almost a keel—a condition usually ascribed to precocious fusion of the suture. Again, in some examples there was that conical bulging of the occipital squama which has frequently been described, with a sharp step from the parietal to the occipital bone along the lambdoid suture. We cannot speak as to the relative frequency of this feature, but the impression is left that it is more frequent in the metopic than the non-metopic group.

TABLE IV.

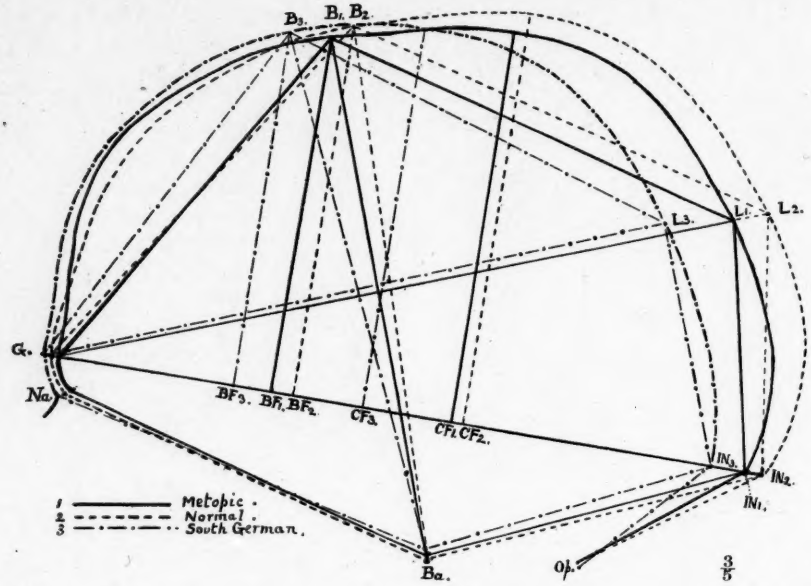
	Metopic series (50)			Normal series (100).		
	Min.	Max.	Mean.	Mean.	Min.	Max.
Glabella-inion length	166	189	176·12 (49) one omitted.	182·37	167	196
	(166)	(194)	(176·54)			
Glabella-lambda length	160	190	175·16	184·75	172	198
Calvarial height	84	111	99·5	103·37	94	117
Calvarial-height index	50·60	63·42	56·39	56·68	50	67·5
Maximum breadth	126	150	138·82	140·7	131	152
Calvarial height-breadth index	65·54	77·37	71·67	73·46	65	83
Calvarial height foot-point distance from glabella.	88	113	100·12	105·73	91	123
Calvarial height foot-point positional index.	51·76	63·22	56·70	57·93	50	66
Bregma foot-point distance from glabella.	45	66	54·96	61·96	51	78
Bregma foot-point positional index.	26·79	36·74	31·10	33·89	27·5	42
Length of frontal chord	103	120	109·50	116·49	105	132
Glabella-bregma chord	95	115	104·78	111·62	101	126
Frontal arc length	118	143	128·06	133·54	120	152
Frontal arc height	22	33	27·94	27·32	20	34
Glabella-bregma arc height	18	28	23·1	21·69	15	30
Curvature index of os frontale	19·29	30·84	25·48	23·42	17·54	27·64
Glabella-bregma arc index	16·96	27·27	21·96	19·57		
Length of parietal chord	96	127	112·38	115·15	104	126
Parietal arc length	111	146	123·82	127·83	112	143
Parietal arc height	19	31	24·4	23·49	16	30
Curvature index of os parietale	16·81	24·40	20·79	20·36		
Parietal frontal arc index	87·50	114·06	96·79	95·97	80	101·5
Lambda-inion chord	50	78	62·68	65·19		
Lambda-inion arc	51	83	66·80	69·76	50	95
Occipital arc height	4	16	9·42	9·76	3	19
Curvature index of os occipitale	7·27	24·24	14·83	14·81		
Basi-bregmatic height	120	145	130·20	133·71	123	147
Basi-nasal length	88	108	97·76	100·96		
Inion-basion length	71	95	83·32	86·44	68	97
Bregma angle	53°	64°	58·28°	56·33°	50°	63°
Lambda angle	68°	90°	78·23°	81·95°	70°	88°
Opisthionic angle	31°	47°	37·22°	35·13°	22°	41°

The absolute measurements and indices utilised for the detailed analysis of the characters of the vault are shown in Table IV. side by side with the corresponding values for a normal male series of 100 skulls.

In accordance with the smaller average size of the metopic as compared with the normal skull, there is a general decrease in the mean values of the absolute linear measurements; the only exceptions among those recorded being the heights of the frontal, parietal, and occipital arcs, which are approximately equal severally in the two series. When attention is directed to the indices and angles, however, differences in the mean values in the two series become evident in some cases. The glabella-inion length and calvarial height are correspondingly diminished in the metopic group, with the result that the mean calvarial-height index remains practically unchanged. The calvarial height being diminished to a greater extent relatively than the maximum breadth, the mean calvarial height-breadth index is less in the metopic series than in the normal series to the extent of about two points. The bregma foot-point, or point of intersection of a perpendicular from the bregma on the glabella-inion line, and calvarial-height foot-point, or point of intersection of the perpendicular from the highest point of the vault on this same line, are on the average less distant from the glabella in the metopic than the corresponding points in the normal skull. When the positional indices of these points are compared in the two series it is evident that these points of intersection are relatively and proportionally as well as absolutely further forward, and this is more evident in the former than the latter. The frontal bone is shorter on the average in the metopic than in the normal skull, as is evident from a comparison of the mean frontal arcs and also the frontal chords in the two types. The forward position, however, of the bregma foot-point is also in part accounted for by the more vertical position of the frontal bone in the metopic group. This is shown by the appreciable increase in the size of the bregma angle. On the average this angle is greater in the metopic type than the non-metopic by two degrees. The lambda angle, on the other hand, shows a distinct increase on the average in the normal compared with the metopic skull, so that, while there appears to be an elevation of, or more vertical disposition of, the vault of the metopic skull in front, there seems to be a distinct tendency to flattening in the posterior section above the glabella-inion plane, with a partly compensatory increase below that plane, as is shown by the mean values of the opisthionic angles. While the mean curvature of the parietal and occipital arcs is very similar in both metopic and non-metopic skulls, as is evident from the practically identical mean curvature indices of the parietal and occipital bones, in the case of the whole frontal arc, and to an almost equal degree in the glabella-bregma

portion of the arc, the curvature is distinctly more marked in the metopic than in the non-metopic skull, there being a difference of fully two units in the indices.

There is no marked difference in the mean relation of the parietal to the frontal arc in the two types. This is shown by the slight difference, less than one unit, in the mean parietal-frontal-arc indices in the two groups. There is only a difference of about two units in the mean lengths of the lambda-inion chords and about three units in the lambda-inion arcs in favour of



the non-metopic group in each instance, so that, while there is present, posteriorly the flattening above the glabella-inion plane already referred to, it is evident that the morphological changes incidental to the persistence of the suture are more marked in the forward portion of the skull.

The method of analysis adopted permits of a reconstruction, from the data, of an ideal outline representing the means of the series compared. Owing to the uniformity of the series these means are not mere abstractions, but represent the type with minor variations eliminated. If now the outlines with their inscribed lines be superimposed, we obtain a graphic representation of the facts detailed above (fig.). The outlines are erected on Schwalbe's base line—glabella-inion,—and so adjusted that the points

representing the basion in each as nearly as possible coincide. Examination of the figure shows that the glabella-lambda lines exactly coincide. The same relative proportions are maintained in the occipital region in both metopic and non-metopic skulls, and the glabella-lambda and glabella-inion planes bear the same relative position to one another. It will be observed, however, that the lambda points (L_1, L_2) are further removed from one another than the inion points ($In._1$, $In._2$). This accounts for the diminution of the lambda angle in the metopic outline, and for the flattening of the hinder part of the vault referred to above. This flattening in a more pronounced degree is characteristic of brachycephalic skulls, and the outline of a South German metopic skull with an index of 88 has been introduced into the figure for comparison. It will be noticed that the flattening is here associated with a still more acute lambda angle, the glabella-lambda diameter being reduced relatively more than the glabella-inion diameter. The figure brings out clearly the reasons for the forward position of the bregma and the increase in the bregma angle in the metopic skull. The approach to the brachycephalic characters of the frontal region is shown by the comparison with the South German contour, in which the relative forward shifting of the bregma is a marked feature.

As a result of the above analysis it thus appears that the greater brachycephaly of the metopic specimens in a series is not merely a matter of relative proportions of the diameters, but is associated with changes in the characters of the vault.

Summary and Conclusions.

In the section on gross measurements the conclusion was arrived at that the frontal expansion in metopic skulls was not merely compensatory. The cranial capacity being but slightly diminished, while the length and height are reduced and the breadth remains stationary, the correlations worked out suggested that the factors of growth were modified so as to attain a given capacity by a method different from the normal, viz. a greater expansion in the forward and a smaller development in the hinder part of the vault. There is some evidence, although it is not very decisive, that with the persistence of the sutures in the frontal region there is a tendency to an earlier fusion of those in the region of the lambda. The detailed analysis confirms and amplifies these points, and tends to show that metopism is one feature only in a general change in the morphological characters of the vault.

For some reason unknown the stress of expansion exerts itself in the transverse rather than in the longitudinal and vertical directions, and this stress is at its maximum in the frontal region. In a brachycephalic series

the result is an exaggeration of the typical brachycephalic characters, while in a dolichocephalic series brachycephalic characters are assumed. In short, metopism is not to be explained merely by a supposed expansion of the frontal regions of the hemispheres, but rather as an adjustment of the brain-case as a whole to its contents. To put it very crudely, for the case of the long oval type of skull metopism provides for the adaptation of a dolichocephalic brain-case to a more brachycephalic type of brain. As stated above, one of the motives underlying the detailed observations recorded was the hope that possibly some facts of more general interest might emerge. The data obtained, however, though not without a bearing on the larger issue of skull-form in general, do not carry us far, and we must be content with having demonstrated, in fuller detail than has hitherto been attempted, how the skull-form is modified when there is persistence of the metopic suture.

NOTES ON SOME MEASUREMENTS MADE ON SUBJECTS IN THE DISSECTING-ROOM.

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I. Introduction.

Since the spring of 1909 I have collected measurements of the length and breadth of the head and skull made on 160 dissecting-room subjects. Most of the work was done by myself, but I acknowledge my indebtedness to the attendant at the Anatomy School (Mr John Lane) for his assistance in increasing the number of records. The heads were measured (when the subject was brought into the dissecting-room), and, the exact spots touched by the calipers having been marked, the soft tissues were here incised down to the bone, and the measurements repeated upon the skull.

In this way I hoped to obtain a reliable series of data comparable to those recorded by Czekanowski[1] from the Anatomy School at Zürich. Czekanowski's Inaugural Dissertation is the most complete piece of work on this subject known to me, though I hasten to mention that of Gladstone.[2] But the latter investigated fewer points, and with a different object in view.

Czekanowski dealt with "material" representative of the Alpine race of Central Europe. He obtained some interesting results illustrative of the difference between the breadth index of the head and the corresponding

[1] Czekanowski, *Das Verhältnis der Kopfmasse zu den Schädelmassen:* Inaugural Dissertation, Zürich, 1907 (published by Vieweg, Braunschweig).

[2] Gladstone, Dr R. J., *Biometrika*, vol. iv., article iii., pp. 105 *seq.*

index of the skull. He published a sliding scale to show how the differences are modified according to the absolute value of the index. For instance, where the index of the head is about 75, the sum of 1·3 units is to be subtracted if it be desired to obtain the index for the skull; whereas when the head provides an index of about 89, the difference in the "cranial" index is nil, and above 89 it may even be necessary to add to the "cephalic" index in order to arrive at the proper value for the "cranial" index.

This result is so different from the rough-and-ready mode of subtracting two units from the index provided by the head (and thus to arrive at the index for the skull), that it demands criticism, and above all confirmation from data supplied by dolichocephalic types. For, as noted above, Czekanowski worked upon the brachycephalic type common in Central Europe.

To my regret, I soon found myself unable to provide evidence of a reliable nature bearing upon this matter. Czekanowski measured cadavera to all intents equivalent to what we should call "post-mortem room" bodies. At Cambridge, on the other hand, the bodies must remain intact for six months at least before the scalp is shaved and final preparations render them suitable to the uses of the dissecting-room. The lapse of time brings with it pressure effects which distort the soft parts. The breadth measurement is chiefly affected, and if several bodies have been packed closely for storage the distortion is usually considerable.

But while I recognise failure in this respect, I think the data derived from these cadavera at Cambridge are worthy of publication. At least the skull-measurements are reliable, and we do not possess too much material definitely "sexed" and comparable with such, for instance, as is represented by the Whitechapel or the Moorfields series, or again the Glasgow collections.

II. Summary.

With this introduction I proceed to give some account of my results, prefacing the latter simply with two remarks. First, that data derived from dissecting-rooms need critical consideration, and those who collect such data should be careful to explain the conditions under which the data were obtained. Secondly, and by way of summary, I will state here that the analysis of my measurements seems to show conclusively that the dissecting-room subjects fairly represent the less well-nourished sections of the general British population. And herein is confirmation of what is believed (though on quite different evidence) to be the case.

III. The Material.

One hundred and twenty male heads were measured, and in all, save two, the corresponding cranial dimensions were obtained.

Forty female heads were measured, and in all, save four, the corresponding cranial dimensions were obtained.

IV. Measurements and Age of Subjects.

The measurements made are those of maximum (glabello-occipital) length, and maximum (biparietal) breadth. From these two dimensions the breadth index has been calculated.

In regard to age: the average for the males was about 62, and for the females about 67. Both groups are therefore comparable with the oldest individuals observed by Gladstone (*Biometrika*, vol. iv. p. 110).

The measurements and the indices resulting from these are given in Table I. For the sake of convenience only, groups of ten were made, and the several totals can be used as a measure of the homogeneity in the whole series.

Table I.—Male Subjects.

H.L. indicates head length (max.) glabello-occipital; H.B., head breadth; Sk.L., skull length; Sk.B., skull breadth; B.I., breadth index of head or skull.

No.	H.L.	H.B.	B.I.	Sk.L.	Sk.B.	B.I.	No.	H.L.	H.B.	B.I.	Sk.L.	Sk.B.	B.I.
1	180	144	80·0	174	134	77·0	21	185	144	77·8	183	137	74·9
2	212	160	75·0	202	151	74·8	22	196	151	77·0	187	143	76·5
3	197	148	75·0	191	143	74·8	23	195	149	76·4	187	132	70·6
4	197	164	83·3	184	141	78·7	24	184	154	83·6	176	137	77·9
5	199	151	75·8	193	142	78·5	25	202	152	75·3	195	143	73·3
6	190	154	81·0	182	136	74·7	26	201	144	71·6	192	132	68·7
7	192	148	77·0	183	142	77·5	27	200	159	79·5	193	151	78·2
8	202	156	77·2	190	146	76·9	28	202	135	66·8	195	129	66·2
9	190	154	81·0	...	...	?	29	194	155	80·0	185	147	79·4
10	197	156	79·2	188	143	76·0	30	191	149	78·0	186	144	77·4
	1956	1535	784·5	1687	1278	683·9		1950	1492	766·0	1879	1395	743·1
11	201	158	78·7	183	142	77·6							
				1870	1420	761·5							
							31	192	153	79·7	187	148	79·2
12	198	162	81·7	...	...	?	32	191	152	79·6	186	148	79·6
13	197	162	82·3	190	148	77·9	33	190	157	82·6	188	151	80·3
14	198	155	78·3	188	146	77·6	34	199	154	77·4	196	149	76·0
15	202	158	78·3	193	150	77·7	35	175	142	81·1	169	138	81·7
16	190	152	79·9	188	140	74·5	36	203	148	72·9	198	143	72·2
17	199	160	80·3	190	143	75·3	37	200	154	77·0	190	144	75·7
18	199	145	72·9	189	137	72 5	38	190	149	78·4	185	142	76·7
19	193	164	85·0	180	151	83·9	39	197	158	80·2	188	145	77·2
20	195	152	78·0	186	135	72·6	40	197	150	76·2	192	145	75·6
	1972	1568	795·4	1504	1150	612·0		1934	1517	785·1	1879	1453	774·2

TABLE I.—MALE SUBJECTS (*continued*).

No.	H.L.	H.B.	B.I.	Sk.L.	Sk.B.	B.I.	No.	H.L.	H.B.	B.I	Sk.L.	Sk.B.	B.I.
41	204	159	77·9	196	149	76·0	81	198	163	82·3	188	145	77 1
42	196	147	75·0	189	140	74·0	82	196	147	75·4	186	133	71·5
43	191	143	74·9	181	136·5	75·4	83	200	163	81·5	190	145	76·3
44	185	144	77·9	180	134	74·5	84	195	143	73·3	188	134	71·3
45	197	155	78·7	190	144·5	76·0	85	198	158	79·7	188	145	77·1
46	190	151	79·5	182	139	76·4	86	193	156	80·8	185	142	76·7
47	199	157	78·9	189	147	77·8	87	204	162	79·3	193	148	76·7
48	198	155	78·3	188	137	72·9	88	198	156	78 7	191	138	72·2
49	199	158	79·4	192	147	76·6	89	185	140	75 7	179	133	74·3
50	185	154	83·7	179	146	81·6	90	198	150	75·7	190	143	75·2
	1944	1523	784·2	1866	1420	761·2		1965	1538	782·4	1878	1406	748·4
51	196	152	77·5	190	144	75·8	91	194	156	80·4	188	146	77·7
52	190	146	76·8	183	138	75·4	92	190	142	74·7	185	137	74·0
53	188	147	78·2	180	140	77·8	93	192	158	82·2	184	143	77·7
54	194	152	78·4	188	144	76·7	94	195	154	79·0	189	140	74·1
55	181	143	79·0	176	137	77·8	95	185	143	77·3	177	133	75·1
56	196	156	79·6	191	148	77·5	96	195	153	78·5	189	147	77·8
57	186	150	80·7	180	144	80·0	97	194	140	72·2	186	132	71·0
58	196	155	79·0	191	147	77·0	98	185	148	80·0	177	141	79·6
59	199	153	76·9	190	143	75·2	99	199	151	75·9	193	140	72·6
60	199	144	72·4	192	137	71·4	100	196	147	75·5	189	137	72·5
	1925	1498	778·5	1861	1422	764·6		1925	1492	775·7	1857	1396	752·1
61	194	153	78·8	185	144	77·8	101	199	157	79·0	193	149	77·2
62	184	142	77·2	174	130	74·8	102	197	138	70·1	188	131	69·7
63	204	154	75·4	194	144	74·1	103	191	143	74·9	187	138	73·8
64	200	155	77·5	194	141	72·6	104	187	152	81·3	181	142	78·5
65	188	157	83·4	179	140	78·2	105	196	152	77·6	189	142	75·2
66	205	146	71·2	200	141	70·4	106	212	164	77·4	199	151	75·9
67	190	146	76·8	184	140	76·1	107	207	153	74·0	198	142	71·7
68	200	153	76·5	192	142	73·8	108	184	140	76·2	175	130	76·5
69	186	141	75·8	180	129	71·6	109	182	140	77 0	174	134	77·0
70	194	169	87·0	182	150	82·3	110	186	150	80·6	183	142	77·5
	1945	1516	779·6	1864	1401	751·7		1941	1489	768·1	1867	1401	753·0
71	199	156	78·4	192	139	72·6	111	179	139	77·6	171	135	79·0
72	187	145	77·5	177	134	75·7	112	180	140	77·8	174	132	75·9
73	198	153	77·3	191	145	75·9	113	194	155	79 9	184	142	77·2
74	193	151	78·2	183	141	77·0	114	195	159	81·6	184	145	78 8
75	198	149	75·2	186	137	73·6	115	198	149	75·2	195	144	73·9
76	198	149	75·2	193	139	72·0	116	200	152	76·0	193	143	74·0
77	197	149	75·6	189	140	74·0	117	198	158	79·8	190	147	77·3
78	194	155	79·7	185	145	78 3	118	198	155	78·3	189	141	74·6
79	199	149	74·8	190	139	73·1	119	192	154	80·2	182	145	79·7
80	182	155	83·8	177	149	84 0	120	188	148	78·7	180	131	72·8
	1945	1511	775·7	1863	1408	756·2		1922	1509	785·1	1842	1405	763·2

TABLE I. (*continued*).

FEMALE SUBJECTS.

No.	H.L.	H.B.	B.I.	Sk.L.	Sk.B.	B.I.	No.	H.L.	H.B.	B.I.	Sk.L.	Sk.B.	B.I.
1	184	147	79 9	177	141	79·6	21	198	156	78·8	189	146	77·2
2	194	153	78·9	...	...	...	22	182	148	81·3	173	137	79·1
3	186	148	79·7	180	141	78·3	23	184	149	81·0	178	142	79·8
4	171	152	88·9	...	...	...	24	199	155	77·9	190	149	78·4
5	183	150	82·0	...	...	...	25	190	154	81·0	181	143	79 0
6	196	153	78·0	...	..	...	26	189	147	77·8	180	135	75·0
7	189	140	74·0	179	129	72·0	27	184	142	77·2	177	135	76·2
8	182	148	81·3	171	138	80·7	28	187	147	78·6	180	134	74·4
9	194	152	78·3	183	142	77·6	29	183	137	74·9	176	131	74·4
10	191	148	77·5	182	143	78·5	30	187	154	82·3	179	140	78·2
	1870	1491	798·5	1072	834	466·7		1883	1489	790·8	1803	1392	771·7
11	180	146	81·0	173	141	81·5	31	195	156	80·0	185	141	76·2
12	190	154	81·0	181	143	79·0	32	198	168	84·8	186	149	80·0
13	191	150	78·5	182·5	138	75·5	33	178	143	80·4	173	137	79·1
14	178	144	81·0	172	135	78·5	34	183	141	77·0	171	135	78·9
15	176	137	77·9	171	132	77·2	35	176	149	84·6	171	139	81·2
16	188	154	81·9	180	143	79·5	36	185	144	77·8	181	140	77·4
17	184	143	77·7	175	136	77 7	37	180	144	80·0	172	139	80·8
18	178	140	78·7	172	135	78·5	38	183	147	80·3	179	139	77·6
19	186	144	77·5	176	137	77·8	39	184	145	78·8	179	139	77·6
20	193	150	77·7	183	135	83·8	40	180	142	78·9	174	136	78·2
	1844	1462	792·9	1765·5	1375	789·0		1842	1479	802·6	1771	1394	787·0

CAMBRIDGE DISSECTING-ROOM BODIES.

Males, No. 118 *or* 120.

Heads.—Means.					*Skulls.—Means.*				
Group.	No. of Examples.	L.	B.	B.I.	Group.	No. of Examples.	L.	B.	B.I.
1	10	195·6	153·5	78·45	1	10	187·0	142·00	76·15
2	10	197·2	156·8	79·54	2	8	188·0	143·75	76·50
3	10	195·0	149·2	76·60	3	10	187·9	139·50	74·31
4	10	193·4	151·7	78·51	4	10	187·9	145·3	77·42
5	10	194·4	152·3	78·42	5	10	186·6	142·0	76·12
6	10	192·5	149·8	77·85	6	10	186·1	142·2	76·46
7	10	194·5	151·6	77·96	7	10	186·4	140·1	75·17
8	10	194·5	151·1	77·57	8	10	186·3	140·8	75·62
9	10	196·5	153·8	78·24	9	10	187·8	140·6	74·84
10	10	192·5	149·2	77·57	10	10	185·7	139·6	75·21
11	10	194·1	148·9	77·87	11	10	186·7	140·1	75·30
12	10	192·2	150·7	78·51	12	10	184·2	140·5	76·32
Nos. 1–60	60	...	...	78·23 (60)	Nos. 1–60	58	...	...	76·1 (58)
Nos. 61–120	60	...	...	77·95 (60)	Nos. 61–120	60	...	...	75·4 (60)
Nos. 1–120	120	194·3	151·5	78·01 (120)	Nos. 1–120	118	186·7	141·3	75·8 (118)

TABLE I.—CAMBRIDGE DISSECTING-ROOM BODIES (*continued*).

Females.

Heads.—Means.					*Skulls.—Means.*				
Group.	No.	L.	B.	B.I.	Group.	No.	L.	B.	B.I.
1	10	187·0	149·1	79·85	1	6	178·8	139	77·7
2	10	184·4	146·2	79·29	2	10	176·6	137·5	78·9
3	10	188·3	148·9	79·08	3	10	180·3	139·2	77·2
4	10	184·2	147·9	80·26	4	10	177·1	139·4	78·7
Nos. 1 to 40	40	186	148·0	79·6 (40)	Nos. 1 to 40	36	178·1	138·7	78·2 (36)

V. AVERAGES AND VARIABILITY.

The various means, standard deviations, and coefficients of variability are set out in Table II., and in Table III. I have arranged some of these means in series with comparable figures derived from other sources. The comparison leads to the conclusion mentioned already, viz. that the dissecting-room "material" represents the less well-nourished part of the general British population. Contrasts become marked when such a selected group as that of university students is brought into line.

TABLE II.

Dimension.	Mean.	P.E. of Mean.	S.D.	P.E. of S.D.	C.V.	P.E. of C.V.
Heads of Males [N = 120].						
Length	194·3	±·410	6·646	±·284	3·42	±·146
Breadth	151·5	±·400	6·510	±·118	4·30	±·184
Breadth index	78·01 [1]	±·191	3·260	±·135	4·185	±·179
Heads of Females [N = 40].						
Length	186	±·701	6·610	±·496	3·505	±·265
Breadth	148	±·639	5·990	±·451	4·047	±·305
Breadth index	79·6	±·282	2·646	±·199	3·320	±·250
Skulls of Males [N = 118].						
Length	186·7	±·392	6·325	±·277	3·39	±·146
Breadth	141·3	±·341	5·360	±·241	3·79	±·163
Breadth index	75·8	±·180	2·910	±·127	3·84	±·165
Skulls of Females [N = 38].						
Length	178·1	±·573	5·080	±·404	2·85	±·227
Breadth	138·7	±·500	4·470	±·354	3·22	±·256
Breadth index	78·2	±·247	2·202	±·175	2·81	±·223

[1] This is the mean of all the indices. The "index of the means" is 77·97.

I have not instituted any comparisons in respect of the female heads and skulls, as the number is so small. But I may mention here that these heads and skulls are shorter and broader than those of the males. The female heads and skulls are more brachycephalic than those of the males; and the contrast between the two sexes is in this respect more distinct in the dissecting-room series than (for instance) in the general British population.

TABLE III.

Dimension.	"Material."	Mean value in mm.
Head length (males).	General British population [1] . .	194·00
	118 men of Royal Engineers company [2]	194·90
	120 dissecting-room bodies at Cambridge.	194·30
Head breadth (males).	General British population . .	154·21
	118 men of Royal Engineers company	151·10
	120 dissecting-room bodies at Cambridge.	151·50
Skull length (males).	44 skulls from Moorfields [3] . .	189·10
	137 skulls from Whitechapel [3] . .	189·00
	405 Scottish skulls (M. Young) [4] .	187·52
	184 Scottish skulls (Turner) [4] . .	186·60
	118 dissecting-room bodies (Cambridge).	186·70
Skull breadth (males).	44 skulls from Moorfields . .	143·00
	137 skulls from Whitechapel . .	140·70
	405 Scottish skulls (M. Young). .	139·56
	184 Scottish skulls (Turner) . .	144·30
	118 dissecting-room bodies (Cambridge).	141·30
Breadth index of head (males).	General British population [1] . .	79·71
	118 men of Royal Engineers company [2]	77·50 (*i.e.* index from mean values of length and breadth.)
	120 dissecting-room bodies (Cambridge).	77·97 " " "
	120 dissecting-room bodies (Cambridge).	78·01 (mean of indices).
Breadth index of skull (males).	42 skulls from Moorfields . .	75·50
	131 skulls from Whitechapel . .	74·30
	405 Scottish skulls (M. Young). .	74·36
	184 Scottish skulls (Turner) . .	77·40
	118 dissecting-room bodies (Cambridge).	75·80

Some comparisons of the standard deviation derived from the dissecting-room data, with other records for measurements of the head as distinguished from those of the skull, are given in Table IV. The dissecting-room series is the more variable, and this is due to the errors in measurement arising from

[1] Pearson, *Biometrika*, vol. v. [2] *Ibid.*
[3] Macdonell, *Biometrika*, vol. v. p. 104.
[4] Young, *Trans. Roy. Soc. Edin.*, vol. li. part ii. No. 9, p. 350.

the distortion of the soft parts. It will be noticed that the breadth of the head is more affected hereby than is the length. But for this, the dissecting-room heads would probably resemble more closely in homogeneity those of the general British population.

TABLE IV.—DISSECTING-ROOM SUBJECTS (CAMBRIDGE).

Head Measurements (Males). Values of Standard Deviation.

Dimension.	"Material."	Value of S.D.
Head length.	General British population [1]	6·100
	120 dissecting-room bodies (Cambridge)	6·646
Head breadth.	General British population	4·890
	120 dissecting-room bodies (Cambridge)	6·510
Breadth index.	General British population	2·954
	120 dissecting-room bodies (Cambridge)	3·260

Cranial variability now falls for notice:—

TABLE V.

Skull Measurements. Values of Standard Deviation.

Dimension.	"Material."	Mean value of S.D.
Skull length (males).	44 Moorfields English [1]	5·58
	405 Scottish (M. Young)	5·94
	137 Whitechapel English	6·27
	118 dissecting-room bodies (Cambridge)	6·32
	English in general (M. Young)	6·44
	Scottish (Turner, quoted by Young)	7·41
Skull breadth (males).	405 Scottish (M. Young)	4·76
	English (M. Young)	4·97
	135 Whitechapel English	5·28
	46 Moorfields English	5·31
	118 dissecting-room bodies (Cambridge)	5·36
	Scottish (Turner, quoted by Young)	5·94
Breadth index (males).	405 Scottish (M. Young)	2·53
	118 dissecting-room bodies (Cambridge)	2·91
	42 Moorfields English	3·00
	131 Whitechapel English	3·26

With the exception of the figure for cranial breadth, the values thus provided by the Cambridge dissecting-room material are quite in line with the other data cited. The degree of homogeneity may be termed moderate, situated as the index (standard deviation) is seen to be—midway, that is, between extremes provided by other series. Also, I may remark

[1] References as in Table III.

that the sources of the dissecting-room material are of the most diverse. The female data show greater homogeneity, but, owing to the small number of the individuals observed, no further remarks will be made here on this part of the work.

VI. Correlation of Length and Breadth.

The values of the coefficient of correlation are exhibited below in Table VI.

Table VI.

(r = coefficient of correlation.)

	Dimensions compared.	Sex.	Material.	Value of "r".
1	Head length and skull length.	Male.	Dissecting-room bodies (Cambridge)	·920 ± ·007
		,,	,, ,, ,, (Zürich)[1] .	·969
		Female.	,, ,, ,, (Cambridge)	·943 ± ·008
		,,	,, ,, ,, (Zürich) .	·972
2	Head breadth and skull breadth.	Male.	,, ,, ,, (Cambridge)	·824 ± ·017
		,,	,, ,, ,, (Zürich)[1] .	·940
		Female.	,, ,, ,, (Cambridge)	·831 ± ·027
		,,	,, ,, ,, (Zürich) .	·960
3	Head length and head breadth.	Male.	,, ,, ,, (Cambridge)	·557 ± ·037
		,,	"English" (recorded by Dr Macdonell)	·345 ± ·019
		,,	,, ,, ,,	·402
		Female.	Dissecting-room bodies (Cambridge)	·654 ± ·050[2]
4	Skull length and skull breadth.	Male.	,, ,, ,, ,,	·448 ± ·045
		,,	Scottish series (Dr Young) . .	·454 ± ·026
		,,	Whitechapel English (Dr Macdonell)	·240 ± ·055
		Female.	Dissecting-room bodies (Cambridge)	·616 ± ·059
		,,	Moorfields English (Dr Macdonell)	·619 ± ·055
		,,	Scottish series (Dr Young) . .	·187 ± ·064

A notable feature of this table is the high correlation indicated by the coefficients between the head length and breadth, and again between the cranial length and breadth in the females. In regard to the cranial relation I note that Dr Macdonell has obtained similar results from the female crania at Moorfields. And that author mentions (as one possible explanation) the large proportion of small crania in that collection. I tested the dissecting-room (female) crania by a rigorous method, and find that 13·9 per cent. are certainly to be described as extremely small. This is not a very large proportion, so that Dr Macdonell's alternative explanation (in which the shortness of the series in point of numbers is held accountable) is more probable than that first mentioned.

But the coefficient of correlation of cranial length and breadth in the

[1] The "material" at Zürich was really "post-mortem room" material, and consequently the observations represent natural conditions more closely.

[2] Attention is directed to the high numerical value of this coefficient.

male cadavera demands consideration for a reason entirely different from the preceding one.

The value of the coefficient (·448) is not extraordinary. It is "positive," and it resembles closely the coefficient (·454) obtained by Dr Young from a very long series of Scottish skulls.

The point is that it is of the "positive" order in these and in the great majority of instances.

For there are certain facts which suggest that the relation of cranial length and breadth is really of the "negative" order. I wish to explain as briefly as possible what those facts are, and to show that they are misleading if so interpreted.

In examining collections of skulls I have taken the trouble (in several instances) of ascertaining how the skulls *absolutely* longest differed in respect of their breadth index from those in the same series and of *absolutely* shortest dimensions. The result has been quite striking in most cases (as may be gathered from Table VII. which follows), for the longest skulls provide invariably the lowest values of the breadth index, and *vice versa*.

TABLE VII.

No.	"Material."	Skulls absolutely longest.		Skulls absolutely shortest.	
		No.	Average breadth index.	No.	Average breadth index.
70	Modern Sardinians	21	67·8	21	73·8
50	Aboriginal Australians	24	68·4	26	70·5
100	Scottish (Dr Young's series K) . .	20	72·9	18	75·6
118	Dissecting-room bodies (Cambridge) .	12	73·3	12	77·6
?	Middlesex Hospital (Gladstone) . .	...	76·2	...	80·9
65	Dissecting-room (Zürich) . . .	4	78·4	5	87·4

Even more striking is the result obtained by taking definite values of the breadth index in a regular sequence, and appending to each index the mean values of length and breadth provided by the corresponding crania. Upon this basis I have constructed Table VIII., where the cranial length increases just as regularly as the cranial breadth falls in numerical value. A tendency to compensation seems to exist, as though the sum of length and breadth approached a constant quantity. And if we lose sight of the breadth indexes in Table VIII., the remaining figures suggest strongly that in each of these four instances the length varies inversely as the breadth, or in other words that the correlation of length and breadth is not positive but negative.

A biometrician would smile at the deplorable mental fog permitting such an illusion to persist for more than a moment. Yet I venture to say that the difficulty may easily present itself to, and may need a certain amount of consideration by, those not highly trained in dealing with such data. And this is my excuse for bringing it forward here.

TABLE VIII.

Breadth index not exceeding	Mean corresponding	
	Length.	Breadth.
Dissecting-room bodies (Cambridge) [N = 118].		
84	179·7	150·0
82	178·7	145·0
80	182·6	144·0
78	185·7	143·4
76	187·0	140·97
74	190·2	139·2
72	192·0	136·8
70	186·5	131·0
68	195·0	129·0
"Large" Scottish skulls, series "K" (Dr Young) [N = 100].		
82	178·0	144·0
80	185·3	146·7
78	185·7	142·7
76	188·8	141·5
74	190·4	139·5
72	191·1	137·2
70	193·7	135·0
68	200·0	136·0
Modern Sardinian skulls [N = 70].		
82	170	138·0
78	177·8	138·0
76	182·75	137·1
74	183·6	133·6
72	186·2	132·5
70	188·8	130·2
68	187·0	124·7
Aboriginal Australian skulls [N = 50].		
76	185·0	139·0
74	183·5	134·6
72	188·2	133·7
70	189·8	131·5
68	188·6	128·2

Note.—In each group (as the breadth index falls) the length increases, while the breadth diminishes.

But there is no doubt that really the correlation between cranial length and breadth is of the positive, not of the negative order. And the columns representing lengths and breadths in Table VIII. mislead, because the table is based upon a seriation of indexes, not of the dimensions themselves.

That this is the case might be shown in several ways. I have selected the most decisive, though perhaps not the shortest, method. Commencing with cranial lengths, I took these in successive groups (175 to 180, etc.) and calculated the mean value of the breadth for the skulls in each group. The result is seen in Table IX.

TABLE IX.—DISSECTING-ROOM BODIES (CAMBRIDGE). [N=118. Sex=male.]

Grouping by length.	No.	Mean length.	Mean breadth.	Mean breadth index.
Crania of length not exceeding 175 mm. . . .	7	173·0	133·3	77·4
,, ,, from 175 to 180 mm. . . .	15	178·0	138·6	77·6
,, ,, ,, 180 ,, 185 ,, . . .	23	183·0	141·7	77·3
,, ,, ,, 185 ,, 190 ,, . . .	42	187·8	141·8	75·3
,, ,, ,, 190 ,, 195 ,, . . .	24	192·7	142·8	74·1
,, ,, ,, 195 ,, 200 ,, . . .	6	197·8	145·6	73·8
,, ,, exceeding 200 mm. . . .	1	202·0	151·0	74·8
Total number .	118			

Other considerations arise from this result, but they are not appropriate here, my object being to point out that, where such apparently conflicting results arise as are shown in Table VIII. (the part referring to the dissecting-room bodies) and Table IX., the latter is to be taken as the guide in preference to the former.

VII. RELATION OF THE BREADTH INDEX OF THE HEAD TO THAT OF THE SKULL.

In the introductory section of this paper, I mentioned the circumstances leading to distrust of the results so far obtained in the dissecting-room at Cambridge. In this place I may add that so far as they go those results do not confirm, indeed they tend to contradict, Czekanowski's conclusions. The comparison of the results obtained by various observers fails equally to confirm the sliding scale devised by Czekanowski, so that this scale, although admittedly it holds the field, requires careful scrutiny and testing.

VIII. THICKNESS OF SOFT TISSUES ON SKULL.

Czekanowski and Gladstone have provided data for the estimation of the mean value of the thickness of the soft tissues overlying the cranium.

In the series of bodies measured at Cambridge some comparable data were obtained, and are most easily set out in a table (Table X.). The great discrepancy occurs in respect of the transverse measurements of the dissecting-room bodies. The divergence is so great as rightly to cause the rejection of the aberrant data. Yet I may mention that results as discordant as these have been reported already, the "material" being similar to that used at Cambridge, viz. dissecting-room bodies at Dorpat (Stieda and Wilt [1]). Hagen [1] has recorded equally aberrant results, but from observations on five natives of the Netherlands East Indies.

TABLE X.—THICKNESS OF SOFT TISSUES OF HEAD.

Observer.	Amount of difference.	Sex and age.	Amount of difference.	Sex and age.
A. Difference between head length and skull length.				
Czekanowski . .	7·25 mm.	♂ ? age	6·92 mm.	♀ ? age
Gladstone . . .	7·25 ,,	♂ (aged)	7·12 ,,	♀ (aged)
Duckworth . .	7·6 ,,	♂ (aged)	7·9 ,,	♀ (aged)
B. Difference between head breadth and skull breadth.				
Czekanowski . .	6·91 mm.	♂ (? age)	6·35 mm.	♀ (? age)
Gladstone . . .	7·40 ,,	♂ (aged)	6·98 ,,	♀ (aged)
Duckworth . .	10·2 ,, [2]	♂ (aged)	9·3 ,, [2]	♀ (aged)

[1] Quoted by Czekanowski, *op. cit.*, p. 48.
[2] Unreliable for reasons stated in text.